EXECUTIVE SUMMARY

Managing Water under Uncertainty and Risk

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THE UNITED NATIONS WORLD WATER DEVELOPMENT REPORT 4

UN WATER Report

United Nations Educational, Scientific and Cultural Organization

World Water Assessment Programme

UN WATER

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TABLE OF CONTENTS AND CHAPTER SUMMARY

The WWDR4 opens with Chapter 1, which describes the global dimensions of water and underlines the need to move beyond the concept of water as a sector. It discusses water's central role and cross-cutting nature in achieving various developmental targets, a reality that is evolving in key international processes such as the United Nations Framework Convention on Climate Change (UNFCCC) negotiations and the preparatory work leading up to the Rio+20 Conference of the UN Commission for Sustainable Development (CSD), or being adequately implemented in national frameworks.

Part 1 begins with Chapter 2, which focuses on the key sectors of water demand: food and agriculture, energy, industry, and human settlements. In addition to reporting recent trends and developments, this chapter describes the pressures for the main drivers, the uncertainties and risks related to each sector, projections on future demands (where possible) and possible response measures. The chapter concludes with a section on ecosystems as a 'user' of water, arguing that water demand by ecosystems is to be determined by the water requirements to sustain or restore the benefits for people (services) that we want ecosystems to supply.

Chapter 3 looks at the supply-side aspects of the water resources equation. Focusing on information provided in previous WWDRs, the chapter examines the role of large-scale climate drivers in distributing the earth's water resources over time and space. Two very important storage-related issues, groundwater and glaciers, are addressed here in terms of their vulnerability and the long-terms risks that may evolve from over-exploitation (groundwater) and from climate change (glaciers). The chapter concludes with an examination of the most pressing water quality issues and the risks these can engender.

Chapter 4 focuses on the benefits received through water in terms of human health and ecosystems and the challenges faced from natural hazards and desertification. These are examined in terms of current trends and hotspots, with uncertainties and risks associated with the main external drivers, and response options. The chapter includes a section focusing on gender-related challenges and opportunities and concludes with an examination of the current global water balance, describing the role of water as the nexus for sectors related to development and poverty eradication.

PREFACE

by Olcay Ünver

Coordinator, United Nations World Water Assessment Programme

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Released every three years since March 2003, the United Nations *World Water Development Report* (WWDR), a flagship UN-Water report published by UNESCO, has become the voice of the United Nations system in terms of the state, use and management of the world's freshwater resources. The report is primarily targeted at national decision-makers and water resource managers, but is also aimed at educating and informing a broader audience, from governments to the private sector and civil society. It underlines the important roles water plays in all social, economic and environmental decisions, highlighting policy implications across various sectors, from local and municipal through national to regional and international levels.

Coordinated by the World Water Assessment Programme (WWAP), this fourth edition of the WWDR, released in March 2012, is the result of a concerted three-year effort by UN-Water agencies, in collaboration with dozens of scientists, professionals, NGOs and other UN-Water partners. The report addresses the most salient strategic and technical aspects relating to how and why we need to use, manage and allocate water to meet multiple, often competing goals, from all major policy directions – from poverty alleviation and human health to food and energy security and environmental stewardship. In describing how water underpins all aspects of development, the report provides a critical point of reference for linking water to global policy tracks, such as those for poverty eradication, including the Millennium Development Goals (MDGs); sustainable development, the Rio+20 process; climate change, and the respective COP process.

While the report is factual, containing the most current information available concerning the state of knowledge about our water resources and covering the most recent developments that affect it, the report also provides decision-makers with concrete examples of approaches and potential responses for addressing water-related challenges from both a water management perspective and a broader political and sectoral scope, which covers development, financing, capacity-building and institutional reform.

The fourth edition of the WWDR builds upon the previous three editions. Similarly to the first two editions, it includes a comprehensive and up-to-date assessment of several key challenge areas, such as water for food, energy and human health, and governance challenges such as institutional reform, knowledge and capacity building, and financing, each produced by individual UN agencies. And, as in the third edition, the report offers a holistic and integrated approach to examining the links between water and the drivers that create pressures on the resource, climate change, ecosystems and various aspects of human security as embodied under the MDGs and other key global policy tracks. This fourth edition also continues to focus on how decisions made outside the 'water box' affect the resources and other users, linking water to a number of cross-cutting issues. Through this approach, the report illustrates how interactions between water and a multiplicity of external forces can be incorporated into analyses and decision-making processes in various sectors and domains. It is fortuitous that the release date for this report occurs a few months prior to the Rio+20 Earth Summit, thus providing a sound basis for discussions on the future of our planet in which the centrality of water can be clearly highlighted.

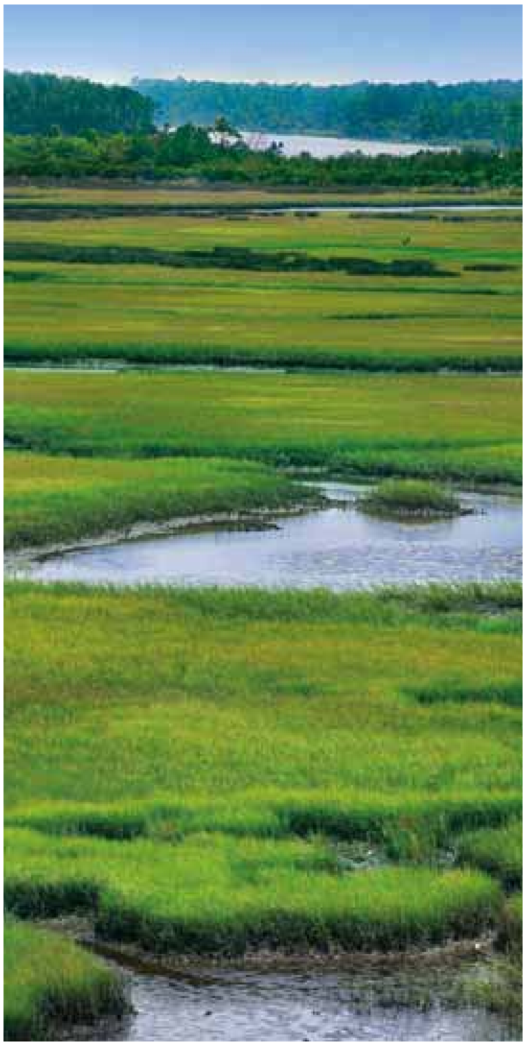
Several new elements have also been added to this fourth edition of the report. For the first time since the inception of the series, the WWDR4 has been developed under an overarching theme – 'Managing Water under Uncertainty and Risk' – which has served as a guide for the authors and collaborating agencies, allowing for the streamlining of the many different contributions into a cohesive narrative. Second, the WWDR4 has been enriched by the addition of five regional reports through the efforts of the five Regional UN Economic Commissions, which complement the challenge area reports by offering a more geographically focused examination of the issues and challenges related to water, including the identification of critical 'hotspots'. Third, this edition reports on the results of the first phase of the WWAP World Water Scenarios Project, which examines possible future developments in externalities that impinge upon water stress and sustainability. Finally, the entire report underwent a gender mainstreaming exercise to ensure that the important gender and social-equity issues were properly and systematically addressed, and a new chapter specifically focused on gender and water has been included in this edition.

In order to help countries improve their self-assessment capability by building on existing strengths and experiences, the report is once again accompanied by a set of case studies from countries around the world highlighting the state of water resources where different physical, climatic and socio-economic conditions prevail.

It is hoped that this report, like its previous editions, will continue to be the main reference document about water and the central role it plays in all aspects of human development, that it will continue to be considered as essential reading for decision-makers, their advisors and anyone interested in – and concerned about – the state and the use of our planet's freshwater resources, and that this edition will reach an ever-widening audience that includes actors outside the 'water box' who make or influence broad socio-economic policies that affect water.

Olcay Ünver

INTRODUCTION



All aspects of social and economic development – often referred to as the *food–energy–health–environment 'nexus'* – depend on water. These activities determine how water is allocated, managed and used, and as they affect the quantity and quality of water resources, they impact on these and all other developmental sectors. Indeed, all of the sectors of the development nexus are interlinked through water.

A combination of growing populations, increasing demands for resources associated with improving standards of living, and various other external forces of change are increasing demand pressures on local, national and regional water supplies required for irrigation, energy production, industrial uses and domestic purposes, as well as for the environment. These forces are undergoing rapid, accelerating and often unpredictable changes, creating new uncertainties for water managers and increasing risks and creating new opportunities for all water users. At the same time, climate change is creating new uncertainties with regard to freshwater supplies and to the main water use sectors such as agriculture and energy, which will in turn exacerbate uncertainties regarding future demands for water. As a result, history is no longer a reliable means of predicting future water demand and availability. As water demand and availability become more uncertain, all societies become more vulnerable to a wide range of risks associated with inadequate water supply, including hunger and thirst, high rates of disease and death, lost productivity and economic crises, and degraded ecosystems. These impacts elevate water to a crisis of global concern.

This fourth edition of the *World Water Development Report* (WWDR4) makes the case that *all water users are – for better or worse and knowingly or unknowingly – agents of change* who affect and are affected by, and connected through, the water cycle.

In today's world, a 'business-as-usual' approach to water management is tantamount to blind neglect of the ecosystems that sustain life and well-being. Past attitudes – which in many cases included an expectation of governments to manage water as a 'sector' while decision-makers in other *true* sectors (food, energy, transport and others) paid little attention to how their actions affected the water cycle (and other users) – have created a disconnect between policies and actions, and the role of managing their consequences. The lack of interaction between the diverse communities of users, decision-makers and isolated water managers has caused serious degradation of water resources and increased the risks to all the developmental sectors that depend upon them.

The WWDR4 also sets a challenge for all water users and the full spectrum of leaders and decision-makers to invest in building and sharing knowledge about how their actions affect water quality, quantity, distribution and use. Only through such a collective effort can ways be found to reduce uncertainty and manage risk to balance and optimize the many fundamental benefits provided to society through water.

CHAPTER 1

Recognizing the centrality of water and its global dimensions

Water is an essential resource required for sustaining life and livelihoods: safe water for drinking, hygiene and providing food; and adequate water to produce energy and support economic activities such as industry and transportation. Water in the natural environment ensures the provision of a multitude of ecosystem services to meet basic human needs and support economic and cultural activities.

Main Message 1: Water underpins all aspects of development: it is the only medium that links sectors and through which major crises can be jointly addressed.

Many economic sectors compete for finite water resources. The challenge for twenty-first century governance is to place water at the heart of decision-making at all levels – horizontally across departments and sectors, and vertically at local, national, regional and global levels. Two prerequisites are essential for this to happen.

First, *it must be understood that water is a natural resource upon which all social and economic activities and ecosystem functions depend.* It cuts across and affects more aspects of life than can be easily listed or categorized. Understanding the multiple aspects, roles and benefits of water is crucial to governing it effectively.

Second, *greater recognition is needed of the fact that water is not solely a local, national or regional issue that can be governed at any of those levels alone.* On the contrary, global interdependencies are woven through water, and decisions relating to water use on a local, national or regional level often cannot be isolated from global drivers, trends and uncertainties. Impacts on water resources are driven by factors both outside the 'water box' and, importantly, outside the 'decision-making box' of local, national and regional actors.

Beyond the concept of water as a sector

Delivering adequate water for social, economic and environmental needs is often understood as the preserve of the 'water sector', which is expected to provide the appropriate infrastructure and channel water in the right direction. It is true that water unites a community of experts, managers, officials and other stakeholders who are tasked with managing and using the resource effectively and responding to increasing demand. As such, its status as a sector cannot be completely denied. Yet in reality, water cuts across all social, economic and environmental activities. Its governance requires cooperation and coordination across diverse stakeholders and sectoral 'jurisdictions'.

The crucial factor for water governance is therefore the recognition that water is not *only* a sector, but also a necessary element that provides benefits for all sectors, thus requiring active consultation with, coordination among, and trade-offs between the sectors and communities that depend upon it. In particular, members of the water community have the duty to inform and provide guidance on decision-making and to regulatory authorities on how to use and manage the resource sustainably, so as to optimize and share its many benefits and minimize conflicts. An equitable sharing of the benefits is particularly challenging in transboundary river basins.

This principle has been captured to a great extent by the movement towards integrated water resources management (IWRM). In the absence of institutionalized IWRM (or a similar coordinating mechanism), growing recognition of the water–food–energy–health–environment nexus concept can help to raise awareness among managers responsible for planning in different water-dependent sectors of the broader implications of their actions, including their water use, on the resource and other users.

Main Message 2: A coordinated approach to managing and allocating water across competing sectors to meet multiple goals also helps ensure that progress made in one sector is not offset by declines in others.

"The crucial factor for water governance is … the recognition that water is not only a sector, but also a necessary element that provides benefits for all sectors."

Recognizing the centrality of water for sustainable development is crucial in the development of a green economy. In a green economy, the role of water in maintaining ecosystem services and water supply would be acknowledged, appreciated and paid for (UNEP, 2011). Managing water sustainably supports the overall objectives of a green economy or a green growth pathway, and also meets critical social imperatives of poverty alleviation, food and energy security, and health and dignity. Direct benefits to society as a whole can be gained by increasing investment in water supply and sanitation, including investment in wastewater treatment, watershed protection and the conservation of ecosystems critical for water. New approaches, such as planning for adaptation to uncertain futures, the adoption of green technologies, improving the efficiency of water provision, and developing alternative water sources and forms of management will play an essential role in enabling a cross-sectoral transition to a green economy.

Embedding water management as the central pillar of sustainable development requires institutions that facilitate discussion and decisions on society's targets and the allocation of water resources to optimize generation and equitable distribution of its many benefits. It is, then, the role of water managers to inform the process and do what is necessary to implement the decisions.

Beyond the basin: The international and global dimensions of water governance

The drivers of water use and availability (and their related uncertainties) can originate from far beyond national and regional boundaries.

Climate change highlights the centrality of water in relation to a key global issue. First, climate change impacts are delivered through a changing water cycle, and their avoidance requires global cooperation on mitigation. Second, impacts in developing countries result in an obligation for developed countries to assist them in adapting to these. Third, efforts to improve water governance arrangements are, in effect, the focus of climate change adaptation needs, and must be explicitly recognized as such in climate change policies and funding. And last, climate change mitigation and adaptation responses are related because the carbon and water cycles are interdependent.

Water is not confined within political borders. An estimated 148 states have international basins within their territory, and 21 countries lie entirely within them (OSU, n.d., 2002 data). In addition, about 2 billion people worldwide depend on groundwater supplies, which include to date 273 transboundary aquifer systems (ISARM, 2009; Puri and Aureli, 2009). The unavoidable reality that water resources do not respect political boundaries demonstrates the supranational dimensions of water, and represents a compelling case for international cooperation on water management. The role of global guidelines and normative legal principles is critical in this regard, and international and regional legal frameworks including conventions provide a strong basis for transboundary cooperation. Awareness is emerging about the need to apply these also to transboundary groundwaters.

Water is a truly global issue through its trade as 'virtual water' (also known as embedded water), which refers to the volume of water used in the production of a good or service. Through this process, countries engage in virtual water trading through products rather than through the physical transportation of water itself, which is a difficult and costly exercise. As a result, billions of tonnes of food and other products that require water to produce are traded globally. Some water-scarce countries have become net importers of virtual water, relying on the importation of mainly rainfed agricultural commodities to meet the food needs of their growing populations. As per capita water scarcity grows, more and more countries may be increasingly incapable of feeding themselves with the amount of water they have available, and will thus have to make trade-offs in their economic, agriculture and trade policies (Figure 1.1).

If society operates within ecological limits, and recognizes the limited availability of water resources globally, it will become impossible for all citizens of the world to consume the same amount of water as the highest consuming individuals (and countries) do today. Therefore, efforts to tackle excessive demand in the developed world need to comprise part of a more equitable distribution of the benefits of water globally if increases in demand within emerging economies and developing countries are to be even partially satisfied without heavily depleting aquifers or irreversibly damaging freshwater ecosystems.

Main Message 3: Global interdependencies will increasingly be woven through water: If no immediate action is taken, regions and sectors without enough water to meet their own needs will need to rely more heavily on others' resources to meet them.

Recognizing water in global policy

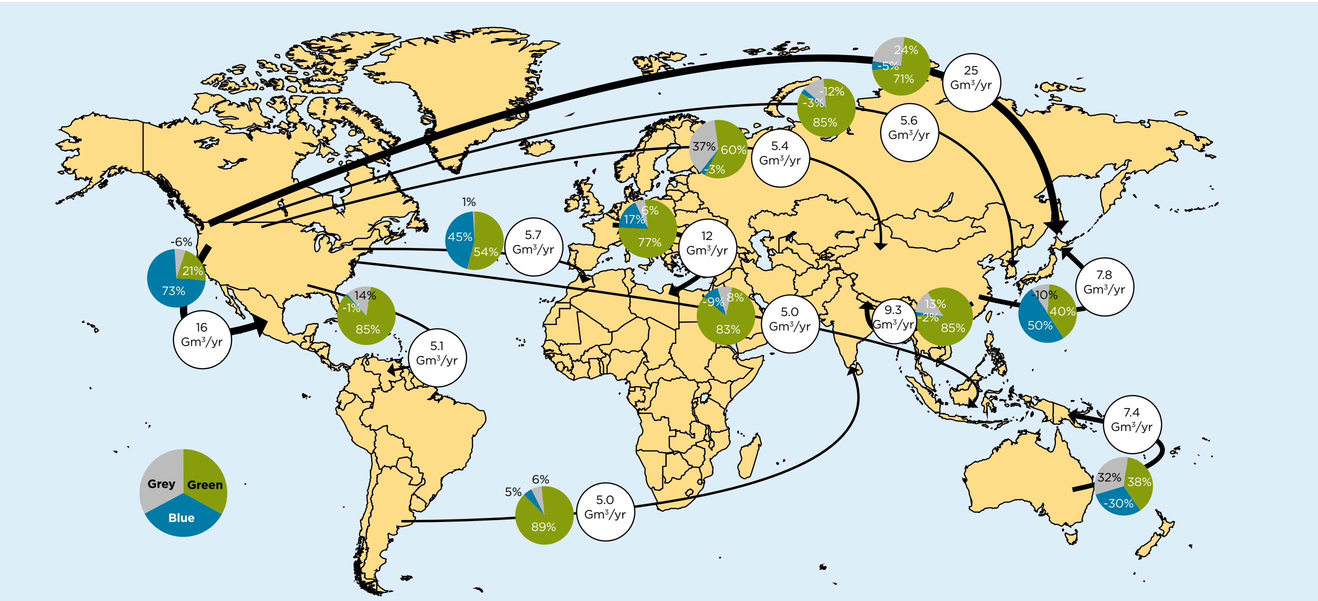
The United Nations Framework Convention on Climate Change (UNFCCC) remains to this day one of the most significant global agreements addressing sustainable development. Despite the multitude of valuable multilateral environmental agreements (MEAs), the UNFCCC has captured the imagination and buy-in of international policy-makers and the general public alike more than any other process on the environment or sustainable development in the past two decades. In this context, ensuring a strong focus on water under the UNFCCC is likely to remain a high priority for the water community.

The United Nations Millennium Development Goals (MDGs) helped to emphasize the existence of a right to development, and that the international community has a responsibility to alleviate global suffering. MDGs also have their limitations, not least in their failure to recognize the cross-cutting nature of water in relation to all MDGs.

One of the targets of the seventh MDG (MDG7), the overall objective of which is to ensure environmental sustainability, is to halve, by 2015, the proportion of the world's population without access to safe drinking water and basic sanitation (Target 7c). However, as

FIGURE 1.1

Global water savings associated with international trade in agricultural products (1996–2005)



Note: Only the biggest water savings (> 5 Gm³ per year) are shown.
Source: Mekonnen and Hoekstra (2011, p. 24).

currently formulated, it fails to consider essential aspects of service provision, such as its quality, mode of provision or access, and affordability.

In 2010, resolutions by the United Nations General Assembly and the Human Rights Council confirmed that access to safe water and sanitation is a human right. Member States are required to ensure the progressive implementation of the right to water and sanitation to everybody in their jurisdiction. It is hoped that this will contribute to accelerating much-needed progress in providing these essential services to billions of people who do not currently enjoy them. According to the measurements and standards of the MDGs, the reports of the World Health Organization (WHO)/United Nations Children's Fund (UNICEF) Joint Monitoring Programme (JMP) for Water Supply and Sanitation, and the Global Annual Assessment of Sanitation and Drinking-Water (GLAAS) processes, 884 million people use unimproved sources for their water supply and 2.6 billion people do not have access to improved sanitation (WHO/UNICEF, 2010). Measured against the more precise and rigorous standards now defined under the right to water, these figures represent a significant under-estimation. Some estimates indicate that the number of people without access to safe and reliable tap water in their homes is between 3 and 4 billion. The push to increase access to drinking water and sanitation to meet the expectations of the right to water could become a major driver shaping the future development of drinking water supply and sanitation services.

It is important that the drinking water and sanitation issues do not divert attention from the need for efforts to enhance institutional arrangements for water resources management. In moving beyond 2015, it will be critical to word each of the new goals in such a way as to recognize the role(s) that water plays in achieving them.

Though debate and dialogue on the appropriateness of these and other specific targets will continue beyond the Rio+20 Conference in June 2012, the consistent messages emerging on water will help to focus and mobilize the water community and ensure that water emerges as a priority issue in the global discourse on sustainable development. However, defining and monitoring targets is a difficult exercise, especially given water's cross-cutting nature, the limited availability of information, and the diversity of local and national conditions.

"The push to increase access to drinking water and sanitation to meet the expectations of the right to water could become a major driver shaping the future development of drinking water supply and sanitation services."

All countries share a responsibility to actively participate in the global forums designed to address and create solutions to impending resource challenges. The water community, and water managers in particular, have the responsibility of informing the process. Implementing the outcomes from global policy agreements will remain a national imperative, but setting the framework requires a widening of the sectoral and spatial horizons of all those who have a stake in water management. However, many of the global policy agreements are made without proper local and national consultation processes and are, in many cases, general agreements that do not reflect the political economy and institutional capacities of the countries, thus compromising the overall effectiveness of respective policies at national and subnational levels.

PART 1

Status, trends and challenges

CHAPTER 2

Water demand: What drives consumption?

Food and agriculture

Water is the key to food security. Agriculture accounts for 70% of total water withdrawals for all (including energy) sectors/human uses, and 90% of all water consumed[1] by these sectors. Relatively speaking, withdrawals for agriculture tend to decrease with increasing levels of development (Figure 2.1). In many countries, water availability for agriculture is already limited and uncertain, and this is set to worsen.

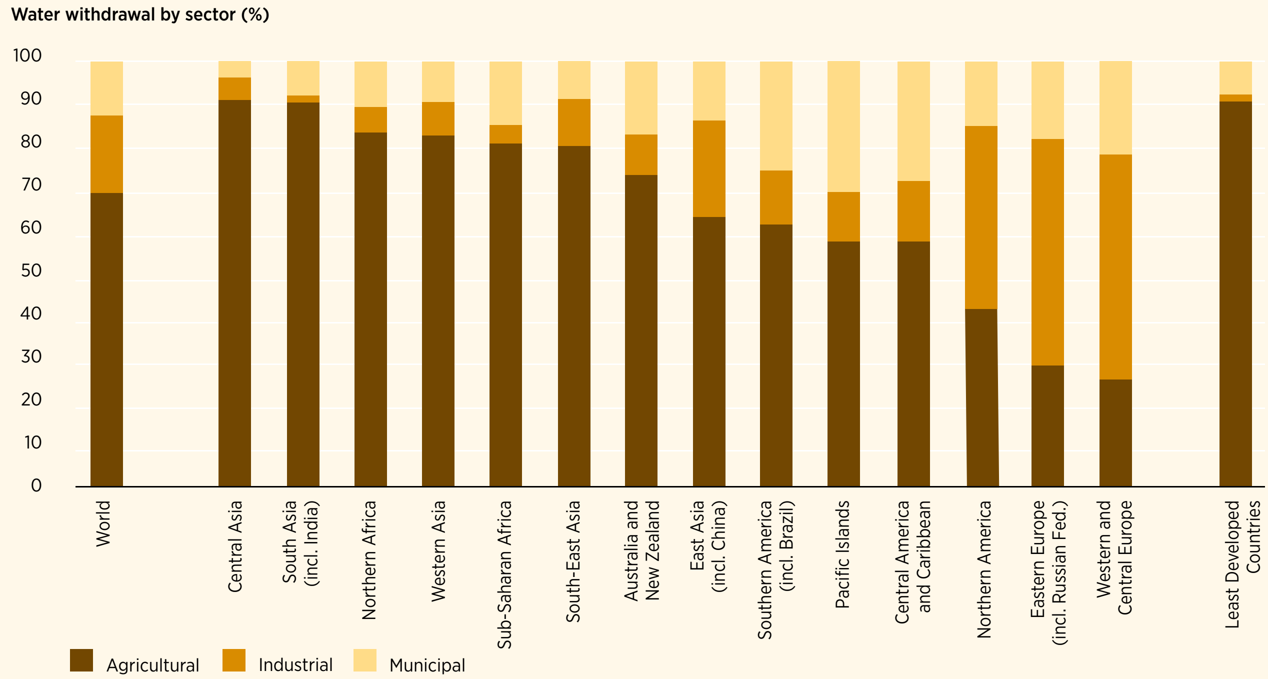
Only about 20% of agriculture's annual water consumption is water from rivers, streams, lakes and groundwater for irrigation purposes – the rest is from rainfed agriculture. However, irrigation crop yields are about 2.7 times those of rainfed farming. Therefore, while irrigation covers less than 20% of the world's cultivated area, it accounts for more than 40% of the world's agricultural production (FAO, 2011*a*). Globally, the area equipped for irrigation increased from 170 million ha in 1970 to 304 million ha in 2008, and there is still potential for expansion, particularly in sub-Saharan Africa and Southern America, provided there is sufficient water available.

The world population is predicted to grow from 6.9 billion in 2010 to 8.3 billion in 2030 and 9.1 billion in 2050 (UNDESA, 2009). Food demand is predicted to increase by 50% in 2030 and by 70% in 2050 (Bruinsma, 2009).

Predicting future water demand for agricultural uses is fraught with uncertainty, as it is influenced by population and income levels, the type of food in demand,

FIGURE 2.1

Water withdrawal by sector by region (2005)



Source: FAO AQUASTAT (http://www.fao.org/nr/water/aquastat/main/index.stm, accessed in 2011).

and quantities consumed. Crop types, yields and efficiency of agricultural production also affect the quantities of water required, while climatic variations add to the uncertainties.

The most recent estimates of future global agricultural water withdrawal for irrigated agriculture is an increase of around 5% by 2050, from 2,743 km^3 in 2008 to 3,858 km^3 in 2050 (FAO, 2011*a*,*b*).Much of the increase in irrigation water consumption will be in regions already suffering from water scarcity.

In essence, the main challenge facing the agricultural sector is not so much growing 70% more food in 40 years, but making 70% more food available on the plate. Reducing losses in storage and along the value chain may go a long way towards offsetting the need for more food production.

The most detrimental aspect of food consumption is food wastage as agricultural products move along extensive value chains and pass through many hands. This is particularly the case in industrialized countries where food is wasted because too much perishable food is produced and not sold, products deteriorate in storage, and food is bought and not consumed and hence thrown away. All this adds up to both a significant waste of food, and also a large waste of the water used to produce it.

The world food economy is being increasingly driven by the shift in diets and food consumption patterns towards livestock products (FAO, 2006*a*).The livestock sector is now changing at an unprecedented pace as demand for food derived from animals (such as meat and dairy, which require more water than starch-based diets) has boomed in the world's most rapidly growing economies (FAO, 2006*b*). Livestock already contributes 40% of the global value of agricultural output and the increasing demand for livestock seems likely to continue (FAO, 2006*a*).

The demand for biofuels has also soared in recent years. Some biofuels are water intensive and can add to the strains on local hydrological systems increasing competition over land and water.

Water use for agriculture, including livestock, has changed the physical and chemical characteristics of freshwater and coastal wetlands and the quality and quantity of water, as well as caused direct and indirect biological changes in terrestrial ecosystems.

The aqua-politics of exporting/importing food versus self-sufficiency will not be easy to resolve. Food-producing countries may not wish to export crops when food security is threatened, and lower income and Least Developed Countries (LDCs) may need to continue over-exploiting water resources to feed their populations to avoid market-imposed high prices. Subsidies for food and other products can distort markets with possible negative implications through trade in virtual water.

A twin-track approach is needed that makes best use of available water: use demand management policies that increase efficiency and productivity (more 'crop per drop') and supply management measures that seek to make more water available through water storage and conveyance to cope with seasonality and increasingly unpredictable rainfall.

Energy

Energy and water are intricately connected. All sources of energy (including electricity) require water in their production processes: the extraction of raw materials, cooling in thermal processes, in cleaning processes, cultivation of crops for biofuels, and powering turbines. Energy is itself required to make water resources available for human use and consumption (including irrigation) through pumping, transportation, treatment, and desalination.

Climate change is a central external driver that affects both water and energy directly; mitigation measures are concentrated around the reduction of energy consumption and carbon emissions, while adaptation means planning for increasing hydrological variability and extreme weather events, including floods, droughts and storms.

EIA (2010) estimates that global energy consumption will increase by around 50% from 2007 to 2035 (Figure 2.2). This increase will be higher in non-Organisation for Economic Co-operation and Development (OECD) countries (84%) than in OECD countries (14%), with the primary driver being the expected growth in Gross Domestic Product (GDP) and the associated increased economic activity.

With regard to primary energy sources, fuel production is expected to increase until 2035. The production of biofuels has significant water impacts because of the water requirements of crops for growth through photosynthesis, along with other water uses at the biorefinery.

Electricity production from renewables is expected to more than double until 2035 (Figure 2.3), with hydropower growing in overall production, but less significantly in percentage than wind, solar and PV (EIA, 2010; WWF, 2011).

Some regions will face more severe water-for-energy stresses than others. WEC (2010) estimates that China, India and the Middle East, which already experience water stresses and are forecast to experience a five-fold increase in electricity production, will increasingly need to explore new technologies for processing primary energies and generating electricity.

Energy production impacts water quality. Thermal, chemical, radioactive or biological pollution can have direct impacts on downstream ecosystems and water users; where emissions are not sufficiently controlled, considerable amounts of agricultural land may be affected by acid rain. Similarly, where water scarcity obliges nations to use non-traditional sources of water (e.g. desalination, brackish water), choices will need to be sensitive to the water and environmental impacts of the additional demand for electricity.

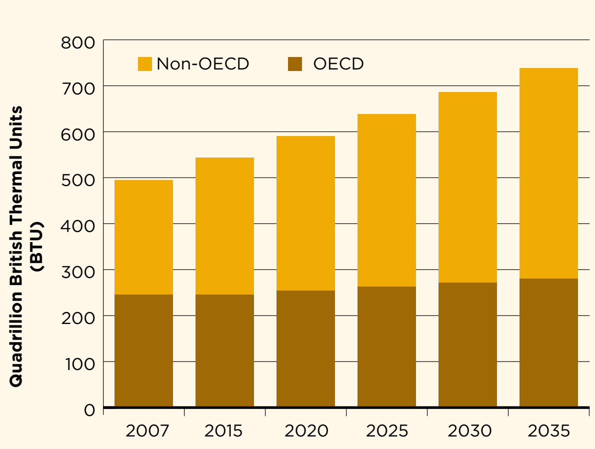
Few countries currently research and report on energy requirements for water. The energy requirements used for surface and groundwater treatment (i.e. removing salts and chemical and biological contaminants) vary largely, based on water quality, technology used and national drinking water standards.

Wastewater treatment requires large amounts of energy (WEF, 1997). High-income countries that have stricter discharge regulations install more energy-intensive treatment technologies. More advanced sludge treatment and processing can consume energy in the range of 30–80% of total wastewater plant energy use (Center for Sustainable Systems, 2008). Because wastewater treatment is generally more energy intensive than standard water treatment, the trend towards higher treatment standards will likely increase the unit energy needs of wastewater treatment in the future for countries moving up in income (Applebaum, 2000). However, it is possible that the introduction of greater energy efficiency and new technologies will offset the expected increases in energy intensity for stricter treatment standards, limiting the projected growth in electricity use at treatment plants.

The cost of desalinated water is closely linked to energy prices, which, despite fluctuations, have been steadily increasing over the past decade (EIA, 2010). Desalination also produces highly concentrated waste brine streams that must be disposed of. Coastal desalination plants discharge that brine into neighbouring waters, with negative impacts on coastal marine ecology. Inland desalination plants face an equal challenge

FIGURE 2.2

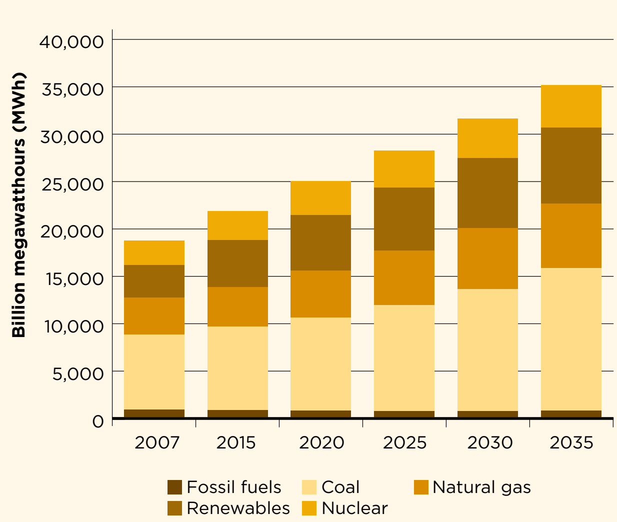
World marketed energy consumption, 2007–2035



Source: EIA (2010, p. 1).

FIGURE 2.3

Projections for world net electricity generation, 2007–2035



Note: For this figure, fossil fuels refers to liquids such as petroleum and liquefied gases. Coal and natural gas are considered separately. Source: Data from EIA (2010).

to find ecologically benign ways to dispose of the brine.

Many high-income societies are moving towards more energy-intensive water because of a push by many water utilities for new water supplies from sources that less conveniently located and of lower quality, and which therefore require more energy to get them to the right quality and location. In addition to treating water to higher standards of cleanliness, societies are also going to greater lengths to transport freshwater from its sources to dense urban areas.

The main challenge with regard to water and energy will be the provision of water resources to ensure that the increased energy needs can be supplied. This need requires policy-makers to promote more efficient and integrated water uses for energy and vice versa. Water and energy policies, which are often made in different government departments or ministries, will need to be integrated with policy-makers increasingly working in close coordination.

Industry

Although industry uses relatively little water on a global scale, it nevertheless requires an accessible, reliable and environmentally sustainable supply. It is generally considered that approximately 20% of the world's freshwater withdrawals are used by industry, although this varies between regions and countries. The percentage of a country's industrial sector water demands is generally proportional to the average income level, representing only about 5% of water withdrawals in low-income countries, compared to over 40% in some high-income ones (Figure 2.1). However, surprisingly little is known about how much water is actually withdrawn and consumed by industry for its manufacturing, transformation, cooling, production and other needs.

Industry's total water withdrawals from surface water and groundwater are usually much greater than the quantity of water it actually consumes. Improved water management is generally reflected in overall decreased industrial water withdrawals or increased wastewater treatment, highlighting the connection between higher productivity and lower consumption, and reduced pollution in effluent discharges, which can have very significant environmental impacts, particularly on regional and local scales (UNEP, 2007). Industries such as agro-processors, textile dyeing, abattoirs and tanneries can cause the presence of toxic pollutants in local water resources. In developing countries the vast majority of industrial wastewater is discharged with little or no treatment (WWAP, 2009).

One approach to decreasing or avoiding environmental degradation from industrial activities, even as industry continues to develop, is through cleaner production and sustainability practices. Cleaner production has many facets, and one of its main objectives is to move toward zero effluent discharges, with industry working to convert wastewater streams into useful inputs for other processes, industries and industrial clusters.

Economic growth and development are the overall main drivers of industrial water use, and that relationship is reciprocal: while economic forces affect water, the availability and state of water resources also influence economic activity. Ecosystem stress, societal values and security are also important drivers, but are typically more local in nature.

International trade – a driver for industry and water – requires that exports from a source country meet environmental regulations in the destination country. Developing countries in particular can face trade barriers in meeting the environmental requirements of developed countries' markets. Industry will find itself increasingly competing for limited water resources as water demands and consumption increase in all sectors, particularly agriculture with its substantial water needs. Thus, all these factors are now subject to greater uncertainty and associated risks.

Industry is generally accustomed to having water available at a relatively low cost. Increasing water scarcity, however, will result in more expensive water supply, including sometimes additional charges for water extraction and wastewater discharges. Undoubtedly, business and industry can play a leading role in sustainable water practices.

The problems surrounding water productivity in industry and broader global water concerns are interrelated. As such, they require integrated management, strategy, planning and actions to provide effective solutions. An integrated approach, promoting proactive measures by industry, including consideration of the needs and interests of affected stakeholders and the environment, will not only anticipate the future, but actually help shape it (BSR and Pacific Institute, 2007).

Human settlements

Between 2009 and 2050, as the world population is expected to increase by 2.3 billion, urban populations are projected to grow by 2.9 billion – from 3.4 to 6.3 billion (UNDESA, 2009). Urban areas are therefore expected to absorb all of the world's the population growth over the next four decades, while also drawing in some of the rural population. Furthermore, most of the urban population growth will be concentrated in the cities and towns of less developed regions which already face enormous backlogs in shelter, infrastructure and services, as well as insufficient drinking water supply, deteriorating sanitation and increasing environmental pollution.

Such unprecedented growth poses a major challenge for city planners. Slums generally present a set of unique problems, including poor housing conditions, inadequate access to safe drinking water supply and sanitation services, overcrowding and insecure tenure; thus, the welfare of those living in these areas are seriously impacted (Sclar et al., 2005). The fastest rising slum populations are concentrated in sub-Saharan Africa, Southern Central and Eastern Asia. Extending basic drinking water supply and sanitation services to reach the poorest people in peri-urban and slum areas is of the utmost importance to prevent outbreaks of water-related diseases in these often overcrowded places and help reduce poverty (WHO/UNICEF, 2006; Garrido-Lecca, 2010).

Worldwide, an estimated 87% of the population gets its water supply from improved sources, and the corresponding figure for developing regions is also high at 84%. Access is far greater, however, in urban areas (at 94%), while only 76% of rural populations have access to improved sources (WHO/UNICEF, 2010). However, these estimates do not take into consideration service quality (e.g. intermittent supply, disinfection, or water quality control) or affordability. The number of urban dwellers lacking adequate provision for drinking water is actually increasing as rapid urbanization continues in many regions (UN-Habitat, 2003, 2010).

In 2010, a reported 2.6 billion people in the world did not have access to improved sanitation facilities. Of the approximately 1.3 billion people who gained access during the period 1990–2008, 64% live in urban areas (WHO/UNICEF, 2010). Again, projected demographic growth in urban areas gives rise for concern: if efforts continue at the current rate, improvements in sanitation coverage will only increase by a mere 2% – from 80% in 2004 to 82% in 2015 – an additional 81 million people (WHO/UNICEF, 2006).

A comparison of the estimates from 2008 with those of 2000 indicates a deterioration in both water and sanitation coverage in urban areas. Over those eight years, in cities and towns of all sizes, the number of people without access to tap water at home or in the immediate vicinity increased by 114 million, and the number of people without access to private sanitary toilets (basic sanitation) increased by 134 million. In both cases, this means an increase of 20% in the number of individuals living in cities who lack access to basic facilities (AquaFed, 2010).

Current efforts to address this challenge are not insignificant. For example, although the percentage of population with access to improved water supply and sanitation services declined between 2000 and 2008, the number of urban residents with access to tap water are estimated to have grown by 400 million (AquaFed, 2010). Other improvements have been made, such as in Northern Africa, South-East Asia, Eastern Asia, and Latin America and the Caribbean, where access to improved sources of drinking water and improved sanitation has significantly increased (WHO/UNICEF, 2010). The Protocol on Water and Health under the UNECE Water Convention has resulted in increased efforts to improve access to drinking water and sanitation in the pan-European region.

Relative to other sectors, water withdrawal for human/drinking water supply is low, representing about 10% of all water withdrawals globally (Figure 2.1). However, rapidly increasing water demands are leading to over-abstraction from aquifers, areas outside cities and upstream watershed areas, depriving other users and challenging ecosystem functions. Excessive groundwater abstraction is resulting in falling water tables, water quality degradation and land subsidence. A growing number of aquifers located in large urban areas are facing pollution from organic chemicals, pesticides, nitrates, heavy metals and water-borne pathogens (UNEP/GRID-Arendal, 2008).

Urban settlements are the main source of point-source pollution, and urban wastewater is particularly threatening when combined with untreated industrial waste. Illegal and unreported releases of untreated wastewater continue to be an issue all over the world. It is estimated that over 80% of wastewater worldwide is not treated and some of it not even collected in sewerage systems (Corcoran et al., 2010).

In most cities worldwide, there has been years of neglected maintenance of water storage, treatment and distribution systems, posing an increasing threat to public health and the environment. As a result, the cost of rehabilitation of water infrastructure is increasing substantially due to their deterioration. This process is more severe in developing countries.

The informal sector often supplies water to households and is unregulated and difficult to monitor. The poorest families in urban areas, often living in informal settlements lacking public services, often end up paying the most – both in absolute terms and as a percentage of their income – for limited quantities of water that are usually unsafe (Briscoe, 1993; Jouravlev, 2004; Garrido-Lecca, 2010).

Water management together with land-use planning for urban areas will need to become more efficient to meet current and growing demand through technology, investment, and comprehensive and integrated planning for multiple users. Water education can play a very important role in this regard by changing behaviour and attitudes in wider society. Investing in the development, maintenance and rehabilitation of drinking water supply and sanitation systems, promoting efficiency in service provision, providing subsidies for the poor, and protecting water resources from pollution and over-extraction are imperative to ensuring access to safe water for all, particularly poor urban populations who are too often left behind.

Ecosystems

Human versus 'environment' or 'ecosystem' demands for water has been the subject of debate for decades. A root cause of early disagreements has been the perception that these are somehow different subjects, thereby promoting conflicts between development and environment or nature conservation interests. But all freshwater ultimately depends on the continued healthy functioning of ecosystems, and recognizing the water cycle as a biophysical process is essential to achieving sustainable water management.

All terrestrial ecosystem services, such as food production, climate regulation, soil fertility and functions, carbon storage and nutrient recycling, are underpinned by water, as are, of course, all aquatic ecosystem services. Water availability and quality, in terms of direct use by humans, are also ecosystem services, as are the benefits ecosystems offer to mitigate the extremes of droughts and floods. Most ecosystem services are inter-related, and particularly so through water. Decisions that favour increasing one service over, or at the expense of, another therefore inevitably involve trade-offs. Importantly, this trading between ecosystem services can also carry with it the transfer of risks through associated ecosystem changes.

The subject of 'water demand' by ecosystems therefore involves identifying ecosystem 'deliverables' and managing water accordingly. The valuation of these services is central to this, and the advances made over the past 20 years provide a range of techniques that can be used in practice. Even for many terrestrial ecosystems (such as forests), values related to water services often exceed more conspicuous benefits (such as timber products and carbon storage).

Comprehensive valuation of ecosystem services is not yet a precise science, but the process illuminates the potential stakes and provides good comparative indications of where priorities should lie. While some services are difficult to value, others are easier because information on how much their losses cost is available. A very large proportion of the capital investment and operational cost of physical water infrastructure is in effect expenditure that compensates for the loss of an ecosystem service, which can therefore be used to indicate the value of that service. The classic example is water quality whereby, with very few exceptions, healthy ecosystems deliver clean water and any subsequent investment in treating a human-induced water quality problem can be attributed to the loss of this ecosystem service originally provided for free.

CHAPTER 3

The water resource: Variability, vulnerability and uncertainty

The hydrological cycle, external stressors on water resources and sources of uncertainty

The distribution of freshwater supplies can be erratic, with different countries and regions receiving different quantities of water over any given year as precipitation delivers water unevenly over the planet from one year to the next. Understanding the spatial and temporal distribution and movement of water is crucial for efficient water resources management, which must take this variability into account.

The hydrological cycle is driven by a complex, inter-related ensemble of dynamic natural processes, which scientists refer to as 'climate forcings'. The Earth's tilt and rotation around the Sun are among the primary drivers of seasonal variations in precipitation and water availability. Atmospheric and oceanic circulation patterns and their interactions are equally important drivers of weather, climate and the hydrological cycle. A better understanding of these phenomena (e.g. the El Niño-Southern Oscillation) and the 'teleconnections' among different drivers can enhance predictive capability in many regions.

The state of water resources is one of constant change, resulting from the natural variability of the Earth's climate system and the anthropogenic alteration of that system and the land surface through which the hydrological cycle is modulated. Specific changes to water resources and the hydrological cycle include:

- Changes in mean surface flows due to natural climate variability at interannual and multidecadal time scales and climate change
- Modifying runoff through storage and inter-basin transfers
- Increased flood potential due to climate change
- Increased water losses due to temperature increase
- Changes in the seasonality (or timing) of flows, especially in snowmelt basins
- Changes in flows from glaciers due to their retreat
- Decreasing snow and permafrost
- Groundwater depletion – losing the buffer against rainfall variability
- Changes in soil moisture (and runoff) due to changing land surfaces for urban settlements or agriculture

The state of water resources is also influenced by withdrawals to meet socio-economic demands, as well as by control measures undertaken to protect human settlements in flood plains and drought-prone regions. These sources of change and the interactions between them create a new level of uncertainty associated with the use and availability of water resources – in addition to existing uncertainties related to the Earth's climate system and hydrological cycle. As a result, it is no longer possible to assume that the future hydrological record will follow the course of the historical record.

It is increasingly evident that a few large-scale climate drivers orchestrate this movement: the El Niño-Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), the North Atlantic Oscillation (NAO) and the Atlantic Multidecadal Oscillation (AMO). Increased understanding of these drivers has led to their use in interannual predictions of hydrology and climate and more efficient resource planning.

The vulnerability of natural long-term storage: Groundwater and glaciers

Groundwater

During the twentieth century, an unprecedented 'silent revolution' (Llamas and Martínez-Santos, 2005) in groundwater abstraction has taken place across the globe, significantly boosting irrigated food production and rural development. The global groundwater abstraction rate has at least tripled over the past 50 years and continues to increase at an annual rate of 1–2%.

Groundwater is now a significant source of water for human consumption, supplying nearly half of all drinking water in the world (WHO/UNICEF, 2011). The abstraction of groundwater accounts for approximately 26% of total global water withdrawal and around 43% of all water consumed in irrigation; two-thirds of the total amount is abstracted in Asia with India, China, Pakistan, Iran and Bangladesh as major consumers (Siebert et al., 2010).

Some of the major aquifer systems still contain large volumes of groundwater but are no longer coupled to contemporary recharge (Foster and Loucks, 2006) and development of the accessible groundwater circulation in these 'fossil' aquifers involves irreversible depletion. Groundwater abstraction rates have not peaked but are dominated by agricultural use in irrigated areas (Siebert et al., 2010). In the world's arid and semi-arid zones, numerous groundwater systems are not resilient enough to accommodate storage depletion under intensive groundwater development.[2] This is true not only for non-renewable groundwater, but also for many aquifers currently being recharged. The result is a progressive depletion of aquifer storage, made apparent by steadily declining groundwater levels.

However, the shallow groundwater circulation that is exploited for all human demands is highly vulnerable. Gradual changes in local groundwater quality have been documented around the world (Morris et al., 2003). The most ubiquitous changes are caused by pollutants produced by humans such as sewage, liquid and solid waste, chemicals used in agriculture, manure from livestock, irrigation return flows and mining residues. A second category results from the migration of poor quality water into aquifer zones including saline intrusion in coastal aquifers or upward migration of highly mineralized groundwater as a result of groundwater abstraction. Climate change and associated sea level rise are expected to constitute another threat to groundwater quality in coastal areas.

In spite of real concerns about unsustainable abstraction rates and aquifer pollution in many parts of the world, groundwater development still presents many opportunities and will continue to do so in the future if carefully managed.

Glaciers

Mountains are the 'water towers' of the world, receiving much more precipitation than the surrounding lowlands. Their contribution to water supply is of particular significance where the lowlands are arid (Viviroli et al., 2003). Most large ice masses are found in regions with sparse human habitation. However, glaciers of the Alps, the Andes, Central Asia, the Caucasus, Norway, New Zealand and Western Canada are important for water supply. In most of these regions glaciers are shrinking with impacts on stream flow.

Rising global temperatures have a particular effect on the relative importance of rainfall and snowfall, and on the rates at which glaciers are melting. In general, mountain glaciers are shrinking worldwide – with some notable exceptions, for example, in the Karakoram (Hewitt, 2005). In the short term, the shrinking of glaciers is adding water to stream flow over and above annual precipitation, thus increasing water supply. In the long term (decades to centuries), those additional sources of water will diminish as glaciers disappear, and the buffering effects of glaciers on stream flow regimes will lessen.

There is a general perception within most government circles that glacier melt and shrinkage will be highly detrimental to future water supply. This perception is almost certainly misplaced. Most glaciers will continue to shrink very slowly, adding water to the streams over and above annual precipitation, but only in very small quantities relative to precipitation.

Water quality

The 'quality' of water is a relative term. The notion of 'good' or 'bad' water quality is not only a function of its state and what it contains, but also depends on what it is used for. Drinking water regulators and health professionals often prefer to use the term 'safe, clean' water: water that has an unclean aspect (e.g. turbidity) may be shunned by people for seemingly 'clean' water that is not safe.

Compared to water quality, water quantity has received far more investment, scientific support and public attention in recent decades. Although there have been some regional successes in improving water quality, there are no data to suggest that there has been an overall improvement in water quality on a global scale.

The quantity of available water is also determined by its quality, as the two are inextricably linked. Without prior treatment, polluted water cannot be used for drinking, bathing, industrial uses or agriculture, and may effectively reduce the amount of water available for use in a given area. The more polluted the water, the greater the cost of treatment required to return it to a useable standard (UNEP, 2010*a*).

Risks to human and ecosystem health are linked to poor water quality, which in turn threatens socio-economic development. The economic costs of poor-quality water in countries in the Middle East and North Africa range from 0.5% to 2.5% of GDP.

Water polluted with toxic substances, such as inorganic compounds and untreated sewage, degrades the function of aquatic ecosystems by reducing the multifaceted goods and services provided by them. As many of the world's poorest people depend directly upon these goods and services for their existence, this situation further complicates efforts to alleviate poverty (MA, 2005*a*,*b*).

In terms of responses, there is a need for cost-effective options for collection, treatment and disposal of human wastes. There is also a need to direct efforts towards industries using or producing toxic substances. The release of toxic wastes from waste dumps and industrial enterprises is also a major threat and expense to the provision of safe water in the developing world.

Development of clean technology and substitution processes, combined with cost-efficient treatment options, is a priority component. The control of non-point sources of pollution, particularly nutrients leading to eutrophication, is an increasing global challenge.

The preventive and collaborative approach described as Water Safety Planning has demonstrated cost savings and improvements in water quality. It requires the engagement of principal stakeholders discharging industrial, agricultural or domestic waste into a catchment area; policy-makers from various parts of government overseeing the implementation and enforcement of environmental regulations; and utilities delivering drinking water to consumers at the tap.

CHAPTER 4

Beyond demand: Water's social and environmental benefits

Water and human health

Improving water resources management, increasing access to safe and clean drinking water and basic sanitation, and promoting hygiene (WASH) can form the primary basis for prevention against a significant majority of the global burden of water-related disease, and thus have the potential to improve the quality of life of billions of individuals.

The global importance of drinking water supply, sanitation and hygiene for improving health is reflected in the MDGs (Goal 7, Target C), which aims to reduce by half the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015. Yet drinking water supply and sanitation, hygiene, and water management in general are also critical for the achievement of most other MDGs.

Identifying trends and hotspots around the interface of water and health is extremely difficult due to challenges in monitoring and reporting, a lack of information on environmental health determinants, and the interplay of non-environmental determinants on health. However, some diseases are clearly on the rise, such as cholera.

Accelerating global urbanization translates into increased exposure to poorly designed or managed water systems and poor access to hygiene and sanitation facilities. This results in an increased risk of outbreaks of diseases transmitted in the absence of sufficient safe water for washing and personal hygiene, or when there is contact with contaminated water. These include diarrhoeal diseases, intestinal nematode infections and trachoma.

Agriculture is essential to food security and adequate nutrition; yet certain practices can adversely impact human health by increasing water withdrawals for irrigation, changing water regimes in agro-ecosystems, and increasing water pollution. Poor agricultural practices can lead to pollution of surface and groundwater with pesticides, nutrients, sediments and other pollutants. Impacts also include increased breeding grounds for disease vectors and contamination of water supplies with pathogens from animal manure. Deforestation can impact human health by removing the forest buffers that contribute to controlling non-point source pollutants from entering watercourses, increasing the concentration of pollutants downstream.

Global climate change impacts such as higher water temperatures, increased precipitation intensity and longer periods of low flows are projected to exacerbate many forms of water pollution and increase the pressure of diseases such as malaria, schistosomiasis and diarrhoea (Bates et al., 2008; Koelle et al., 2005; Zhou et al., 2008). More frequent heavy rainfalls will likely overload the capacity of sewerage systems, resulting in untreated sewage, with its associated pathogens, flowing into water bodies.

In the case of drinking water quality management, there is increasing recognition that addressing the complex root causes of water contamination is a more effective and sustainable approach than reacting to problems after they occur. Studies have shown that the provision of improved sanitation and safe drinking water could reduce diarrhoeal diseases by nearly 90% (WHO, 2008).

Health impact assessments (HIAs) can be used to objectively evaluate the potential health effects of a water policy or project before it is implemented or constructed, and provide recommendations on how to increase positive – and minimize adverse – health outcomes as part of a public health management plan.

Water and gender

Among the many water-related challenges worldwide, the crisis of scarcity, deteriorating water quality, the linkages between water and food security, and the need for improved governance are the most significant in the context of gender differences in access to and control over water resources.

Unsustainable and short-term decisions have an impact on water resources, with different social and economic consequences for men and women in the community. Over the longer term, scarcity created at the local level as a result of this crisis is likely to increase inequity within local communities with regard to access and control over local water resources, affecting poor women the most.

Decisions related to the sharing, allocation and distribution of water between different uses and across regions are most often made at relatively high levels where economic and political considerations can generally play a more important role than social concerns. These decisions impact the water resources locally available to communities. Rural women often rely upon common water resources such as small water bodies, ponds and streams to meet their water needs, but in many regions these sources either have been eroded or have disappeared due to changes in land use, or they have been appropriated by the state or industry for development needs or to supply water to urban areas.

A gender-sensitive approach to development can have a positive impact on the effectiveness and sustainability of water interventions and on the conservation of water resources. Involving both men and women in the design and implementation of water-related interventions furthers development goals, such as reducing hunger and child mortality and improving gender equality (Oxfam, 2005, 2007).

Although it is true that many socially constructed barriers need to be overcome in order to facilitate the involvement of both men and women in decision-making and management of water resources, it is also true that traditional gender roles have often been challenged successfully by developing women's capacities to manage water interventions, and providing them with opportunities to play leadership roles and improve their economic conditions. However, these successes are often limited to the local context, whereas addressing the larger issues, such as providing water rights to women, require long-term commitment from policy-makers, governments, politicians and advocacy groups.

Ecosystem health

Many of the key ecosystem services are derived directly from water, and all are underpinned by it. Trends in ecosystem health, therefore, indicate trends in the delivery of these benefits and provide a key indicator of whether human society is in or out of balance with water. And the trends in ecosystems are clearly indicating that things are out of balance. This instability and degradation in ecosystems increases uncertainty and amplifies risk.

Ecosystem loss and degradation do not always result in an immediately detectable or proportional response in terms of lost ecosystem services. Instead, a 'tipping point' may be reached, at which rapid and catastrophic collapse occurs following a period of apparent stability (e.g. Lenton et al., 2008). This potentially reverses sustainability and progress towards human welfare. The poor usually face the earliest and most severe impacts of such changes, but ultimately all societies and communities would suffer as a result (CBD, 2010).

Some positive trends in developed regions – for example, improvements in managing nutrient loads, wetlands restoration, or a slowing or reversal of biodiversity loss – are offset by accelerated degradation in developing countries. An underlying problem is that industrialized nations are tending to maintain or increase their consumption of natural resources (WWF, 2010), but are exporting their ecological or water footprints to producer, and typically, poorer, nations. In addition, much of the progress in pollution control in developed countries is attributable to the shift of industrial production elsewhere. This is particularly the case for water-related impacts, including through trade in virtual water. This also transfers uncertainty and risk to developing nations less prepared to deal with these impacts.

'Hotspots' for ecosystem service degradation have not been systematically mapped as such, but they correlate closely with areas of water stress and high pollution loads. Rapid development, high population density and growth, industrialization, inequality and poverty, and to some extent limited water availability, characterize the locations of the most impacted ecosystems. Assessments of global or regional trends disguise good progress made at local and national scales. One positive trend is the emergence of more widespread attention to, and practical examples of, ecosystem-based approaches to achieving water management objectives.

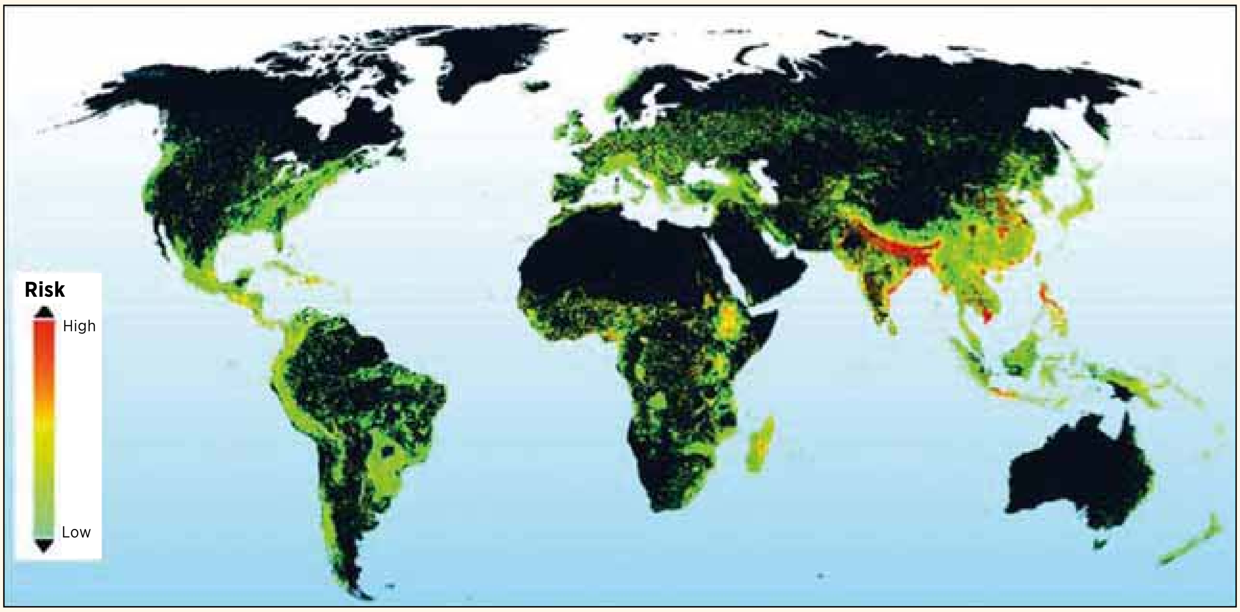
Water-related hazard risk

Water-related hazards account for 90% of all natural hazards, and their frequency and intensity is generally rising. Some 373 natural disasters killed over 296,800 people in 2010, affecting nearly 208 million others and costing nearly US$110 billion (UN, 2011).

Figure 4.1 shows an updated global distribution of mortality risk for three weather-related hazards

FIGURE 4.1

Hazard mortality risk (floods, tropical cyclones and precipitation-triggered landslides)



Source: Developed by the GAR team at UNISDR.

“By 2050, rising populations in flood-prone lands, climate change, deforestation, loss of wetlands and rising sea levels are expected to increase the number of people vulnerable to flood disaster to 2 billion.”

(tropical cyclones, floods and landslides provoked by rains). The areas of highest risk correspond to areas where concentrations of vulnerable people are exposed to severe and frequent major hazards.

The increase in natural disaster losses over the past few decades is largely attributable to the increase in value of exposed assets, while anthropogenic climate change has not had a discernable impact on losses (Bouwer, 2011). By 2050, rising populations in flood-prone lands, climate change, deforestation, loss of wetlands and rising sea levels are expected to increase the number of people vulnerable to flood disaster to 2 billion (UNU, 2004).

Disasters caused by water-related hazards have taken a toll not just on individual lives and livelihoods, but also on national development. Between 1990 and 2000, natural disasters in several developing countries had caused damages representing between 2 and 15% of their GDP (World Bank, 2004; WWAP, 2009). The increasing economic cost and toll of disasters should be a significant incentive for governments and humanitarian organizations to focus more attention on preparedness, prevention and addressing the root causes of vulnerability. To deal with escalating costs, governments are increasingly using insurance mechanisms and weather indexes to help them manage risk more effectively.

Human health is both directly and indirectly impacted by water-related hazards. Outbreaks of waterborne diseases, such as cholera, can occur after disasters as a result of contaminated or inadequate water supplies, sometimes affecting thousands of people and causing many deaths. Outbreaks of vector-borne disease can also occur.

Although investment in disaster risk reduction, including water resources infrastructure, continues to lag, awareness is being raised and quantified evidence is being produced regarding its relative cost-effectiveness. Humanitarians have changed their approach over the past few decades, shifting from response and recovery to a more balanced approach that includes risk reduction. However, complementary capacity-building and financing mechanisms are sorely needed to fill the gap. Given that the cost and frequency of flood disasters is on the rise, investments in preparedness activities and associated infrastructure, flood plain policy development, effective watershed land use planning, flood forecasting and warning systems, and emergency response mechanisms are essential to reducing risks and impacts (UNISDR, 2011).

A recent study of 141 countries found that more women than men die from natural hazards, and that this disparity is linked most strongly to women’s unequal socio-economic status (Neumayer and Plumper, 2007). Mainstreaming gender into disaster risk reduction offers an opportunity for improving disaster resilience and enhancing gender equality and sustainable development.

Impact of desertification on water resources

Globally, desertification, land degradation and drought affect 1.5 billion people who depend on degrading areas, and are closely associated with poverty. While these phenomena affect all regions of the world, they have their greatest impact in Africa, where two-thirds of the continent is desert or drylands.

A number of affected countries face increasing water scarcity. Most drylands have hyper-arid, arid, semi-arid and subhumid climatic conditions with limited water resources, which almost entirely depend on highly variable rainfall for replenishment. Multiple consecutive dry years are experienced during some severe drought periods, resulting in a lack of access to water for many people.

Statistical analysis of rainfall patterns in some of the drylands regions reveals a stepped drop in the early 1970s, which has persisted. Precipitation levels have been reduced by approximately 20%, resulting in a 40% reduction in surface runoff (EC, 2007).

A variety of human activities such as deforestation, veldt fires and inappropriate farming and animal husbandry practices modify the landscape, exacerbating soil erosion, reducing the water retention capacity of soils, and decreasing groundwater recharge and existing surface water storage capacity, all of which eventually lead to increased water scarcity. The draining of wetlands also reduces groundwater recharge.

One of the major impacts of desertification, land degradation and drought-associated water scarcity is felt through food insecurity and starvation among affected communities, particularly in developing countries in the drylands. A lack of efficient and reliable early warning systems and the lack of suitable technological options often limit the flexibility of poor households to make tactical adjustments in drought management practices to reduce losses (Pandey et al., 2007). Where rains are late, farmers mostly delay planting or replant when suitable opportunities arise, and may reduce fertilizer use. When drought leads to prolonged periods of water scarcity, the opportunities for crop management adjustments to reduce losses are often no longer available.

The promotion of soil, water and vegetation conservation, combined with measures to rehabilitate, conserve and protect the natural environment, are prerequisites for sustainable land management. Practising sustainable land management is one of the few options for sustaining livelihoods and generating income without destroying the quality of the land and the water resources, which are needed for agricultural production, food security, protection of biological diversity, as well as preventing and mitigating desertification, land degradation and drought.

In or out of balance?

While per capita consumption of water is decreasing in the industrialized world, overall demand for water is increasing throughout all major use sectors, driven primarily by the growing demands for food and energy in the developing countries and emerging economies. This will invariably increase pressure on the Earth's limited water resources, which in many regions are already experiencing varying levels of water stress.

Food, energy, opportunity for economic growth, human and environmental health, and protection against water-related disasters are all necessary ingredients of development, including income generation and poverty reduction. They all depend on water and can be limited by lack of water. Yet these challenges have too often been dealt with in isolation rather than as part of an overarching and strategic framework across society and the economy. Such an approach further compartmentalizes water in terms of national policies as different ministries and other authorities become responsible for their own commitments, often with limited if any interinstitutional coordination, in terms of health, food and agriculture, energy or urban settlements. In fact, it is these policy decisions that ultimately determine how water resources are allocated.

As a result, different developmental sectors often find themselves in competition with each other for the finite water resources upon which they all depend. In countries and regions where water resources are limited, decisions made to generate benefits from one sector often produce negative consequences for another and generate conflicts, so that the overall economic and developmental gains in one sector are offset by losses in another.

Although it may seem logical to accept that different sectors can be 'in competition' over water, it is clear that all the benefits of water are required for sustainable socio-economic development. Where water resources are limited, certain trade-offs are required to allocate water towards different uses in order to maximize the overall return made up by the benefits water provides though different developmental sectors. Decisions about water allocation and use are not merely social or ethical, but are also economic, such that investing in water infrastructure and management generates increasing returns though these various benefits.

CHAPTER 5

Water management, institutions and capacity development

Why do we need to manage water?

The term 'water management' covers a variety of activities and disciplines. Water resources management is about managing water, as a natural resource and part of the environment, like that found in rivers, lakes, groundwater and other natural water bodies. Water *service* management, in contrast, is basically infrastructure management; it consists of the capture, treatment and delivery of water to the end user; and again capturing the waste streams for reticulation back to a wastewater treatment plant for safe onward discharge. The management of *trade-offs* concerns a range of administrative activities that meet allocation and entitlement agreements across a wide spectrum of socio-economic interests. Each activity has different requirements, but together they add up to what is called *water management*.

Contemporary water managers have to deal with an increasingly complex picture. Their responsibilities entail managing variable and uncertain supplies to meet rapidly changing and uncertain demands – for which the emerging range of drivers and impacts often lie outside the traditional water arena; balancing ever-changing ecological, economic and social values; facing high risks and increasing unknowns; and sometimes needing to adapt to events and trends as they unfold.

During the twentieth century the focus was on structural (i.e. 'hard') options for water management – developing physical infrastructure to 'tame' or 'control' water. Today, most countries that have achieved essential water infrastructure development, have been paying increasing attention to non-structural (i.e. 'soft') management options, most notably associated with the management of trade-offs, and increasingly dependent on institutions, policy, legislation and dialogue among competing users. Most developing countries, however, are still in the process of meeting the most basic levels of water infrastructure development, including storage and public services provision. The challenge for these countries will be to adopt and balance elements of both the *hard* and *soft* paths, in order to maximize the benefits (and minimize the costs and risks, including negative environmental impacts) of both types of approaches.

Innovative infrastructure can sometimes help to overcome the disadvantages of hard infrastructural measures, while maintaining their advantages. Working with nature by using 'green' infrastructure, such as wetlands and less intrusive dams, offers very promising opportunities.

The gradual shift towards policies based on institutional reform, incentives and behavioural change – that seek to reduce the uncertainties and manage the risks related to water resources by embracing more of the non-conventional elements found outside the traditional 'water box' – require significant operational capacity and high levels of coordination among and across various ministries and sectors. This is where the 'integrated' in IWRM becomes of increased importance.

IWRM is defined as a process that 'promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems' (GWP-TAC, 2000, p. 22).

Water allocation and management decisions should consider the effects of each use on the other, thus taking into account overall social and economic goals, including the achievement of sustainable development targets, health and safety. This requires coherent policy-making related to all sectors, most notably between decision-makers concerned with national water security, national food security and national energy security. Ecosystem goods and services and their valuation are increasingly considered in IWRM and planning in order to reconcile economic development and ecosystem maintenance.

The complexity of water management, combined with increased uncertainty, through both socio-economic developments and climate change, makes the traditional command-and-control approach less effective in many situations. An adaptive approach towards IWRM responds to this. Adaptive management is a continuous process of incremental adjustments that attempts to deal with the increasingly rapid changes in our societies, economies, climate and technologies before a catastrophic problem manifests. It is learning to manage by managing to learn.

The importance of water institutions for sustainable development

Water-related institutions function at different scales ranging from the local community to the transnational level, and oversee the allocation, distribution, management, planning, protection and regulation of water resources and services.

Institutions constitute the 'rules of the game', defining roles and procedures for people, possessing of permanence and stability, and determining what is appropriate, legitimate and proper. These 'rules' have evolved organically, responding to history, geography, culture and politics, and reflecting technical advances and the evolution of professional practices and local capacity. Actors other than water managers (i.e. from outside the 'water box') often dictate the rules of the game for water. Consequently, they are often established without water as their central focus and lack recognition of its pivotal importance.

Many water institutions in developing countries are weak and under-financed (Dinar and Saleth, 2005). Most water funding (usually grossly insufficient) goes to infrastructure development and much less is invested in operations and maintenance and developing institutions and human capacities. New funding is required for institutional capacity-building and adaptation, but it is equally important to use existing funding more efficiently.

Conventional water planning is too rigid to meet the challenges ahead, which require the development of adaptive governance frameworks and institutions. Calls have been made for more resilient institutions and approaches (GWP, 2009). In fact, the institutions that govern the management and use of water are not immutable, and have the capacity to change in response to circumstances, particularly crises.

> "Adaptive management is a continuous process of incremental adjustments that attempts to deal with the increasingly rapid changes in our societies, economies, climate and technologies before a catastrophic problem manifests."

Some common features of institutional reforms are the adoption of an IWRM framework, including water resources planning, the establishment of river basin management authorities, the encouragement of multi-stakeholder engagement, and the use of cost-effectiveness, cost recovery and cost–benefit analysis to determine investment priorities. Rights-based approaches to water services, promotion of efficiency through economic regulation (Jouravlev, 2004) and the inclusion of integrity and accountability criteria are other recent developments.

Attempts to tackle mismanagement, corruption, bureaucratic inertia and red tape can prove a major stimulus for institutional change. Corruption is a core symptom of poor governance, which distorts investment, aggravates inequality, increases transactions costs and discourages innovation. All corruption has a particular impact on the poor and disempowered. This calls for, among other things, regulating campaign finance, controlling conflicts of interest, ensuring accountability and timely access to objective and consistent information, promoting public participation, and the enforcement of regulations on the performance and expenditure of service providers.

The precise balance of public and private agencies in the management and delivery of water services differs from country to country – but almost always with the preponderance of the public sector – reflecting a mix of political, ideological and practical factors. It is important to underline that empirical evidence from developed economies reveals that there is little justification for a general presumption in favour of either type of ownership, and case-by-case evaluation of the various trade-offs is therefore in order (Renzetti and Dupont, 2003; Vickers and Yarrow, 1988).

Institutional knowledge and capacity

Improving water management requires comprehensive skills and training in, for example, economics of water use, engineering and infrastructure design and operation, financial and institutional administration, and policy analysis. Recent evaluations have demonstrated that water-related development projects are now decidedly more effective and sustainable than before the mid-1990s (World Bank, 2010a). This can be attributed in large part to stronger institutions, better governance, and better technical and managerial competence in the developing countries whose capacity has been strengthened (Alaerts and Dickinson, 2008). An often under-valuable source of knowledge is experience gained by local water professionals from hands-on management. Local knowledge often goes unrecorded or even unrecognized.

Water institutions are still largely technology and water supply-driven, centred around disciplinary knowledge, based on technological know-how and natural sciences. In a more adaptive approach towards IWRM, knowledge needs to be multi-disciplinary, based on an understanding of society and nature, and able to facilitate integrated approaches so that water institutions and management actors can absorb, adopt and implement new forms of management.

Local managers having access to consistent, timely and reliable information – in a format that is meaningful to them – empowers them to take part in decision-making, and to hold service providers and government more accountable. Information and communication systems can be particularly useful to facilitating the sharing of information and knowledge at local, river basin, national and to some extent international levels. At the national level, establishing sustainable information and communication systems frameworks can significantly contribute to improved decision-making regarding water resources management (MAWF, 2010). At the community level, concrete steps towards sharing information and knowledge, contributing to improved decision-making and resource management can include creating dialogue platforms involving local stakeholders and their assisting service organizations.

CHAPTER 6

From raw data to informed decisions

Data, monitoring and the purpose of indicators

Information is needed about water from all parts of society, from local communities to global multilateral organizations, including farmers, urban planners, drinking water and sanitation utilities, disaster managers, business, industry and environmentalists. Risk management for water resources and their uses implies the monitoring of water-related activities to obtain the data necessary to generate the information required by interested parties.

The challenge is not to simply provide snapshots of information, but an indication of how different dimensions of water and its uses are changing over time in different parts of the world. This effort is based on the assumption that better management of limited water resources requires systematic monitoring to determine whether the many and varied public and private policy objectives set for the resource are being achieved.

Once broad goals and management strategies affecting water have been defined and agreed upon, their effectiveness needs to be monitored. This requires the definition of appropriate indicators and the generation of adequate data. The key objective is to reduce uncertainty about water resources and their use, thereby supporting the management of risks posed by the complex natural systems of which they form a part.

Once sufficient data have been amassed, they can be summarized in the form of indicators to address specific areas of concern. In general, data availability is especially poor for groundwater, water quality, and uses by different sectors (including abstraction, consumption and discharge).

Key indicators

An extensive array of indicators has been developed to monitor the state, use and management of water resources. At a broader societal level, the widely used concept of national water stress measures the amount of water available to a country per person. In order to achieve a balanced allocation and protection of water resources, indicators should be chosen to cover regulation (e.g. technical and performance standards), quota-setting, access rules and allocation procedures, as well as economic instruments (especially pricing mechanisms and payments for ecosystem services).

Aside from simple trends in water availability and use, the water-use efficiency of different sectors in terms of output per unit of water can also be a useful indicator. Similarly, monitoring the proportion of treated wastewater can help to understand the impact of water use on the natural environment. The focus on climate change has also highlighted the importance of selecting appropriate indicators and the importance of sufficiently long time series. However, precondition for any robust indicator is collection of accurate, timely and consistent data that can ultimately be reported at country level.

State of data and information

The monitoring of water resources and their uses represents an immense challenge, especially given the renewable nature and general complexity of water resources, the variability of their distribution in time and space, and the different forms in which they appear. The diversity of monitoring objectives poses additional challenges, and the data required to populate the indicators are seldom systematically or reliably available at global, national, regional or basin levels.

A particular challenge is maintaining a regular flow of comparable data that can be used to monitor trends in different parameters over time, and gaps are often present in historical series. While data gaps have often been patched by the use of models, the quality of the information then becomes dependent on having sufficient field data to calibrate and 'ground truth' the model.

Concerns about climate change have resulted in explicit recognition that the 'stationary hydrology' assumption can no longer be used as the basis for high-level reviews of water availability. This has focused attention on the limited availability of global data on stream flows, on which estimates of country-level water resources availability need to be based. While there are a great deal of available data on precipitation, which can be measured by remote sensing, changes in river runoff or groundwater recharge are much harder to measure. In general, data availability is particularly poor for groundwater and water quality, and in developing countries in general.

Water-use data are often even more difficult to obtain, much less precise and not consistently updated. As an example, data are needed to assess the productivity of water, in terms of GDP per unit of water used, to enable monitoring of the policy objective of decoupling economic activity from resource use. Similarly, the efficiency of water use in different industrial processes may usefully be monitored to determine the efficacy of water demand management programmes. In practice, however, water use is almost always estimated using standard assumptions of water consumption in specific industries.

Without actual use data, improvements in water productivity cannot be tracked, even if they are substantial. The impacts of technological progress may thus be missed unless detailed surveys are carried out into water use by specific sector. Similarly, the lack of knowledge about water use in many sectors means that opportunities and priorities to promote more efficient use of water may not be identified.

These examples highlight the need for greater focus on data generation to enable water managers to monitor the trends of most concern to policy-makers.

Constraints on better monitoring and reporting

Many institutional and political constraints inhibit better monitoring and reporting of information on water resources and their use. Good management generates good data; poor management is frequently a consequence of poor data, while also contributing to the broader data gap.

Because the production of water is a natural rather than a man-made process, there is little certainty in most situations about the initial supply. This distinguishes it from other utility operations and natural resource contexts.

In addition, because water resources are often shared between a number of different political jurisdictions, there is often a disincentive for upstream communities to share information about resource availability and use with downstream jurisdictions, as the information may be used in disputes about the division of the resource. It is also common for private companies to withhold and avoid disclosure of information on water availability and use, alleging that these data are of strategic importance for their business activities.

A further constraint on improved monitoring and reporting is the lack of agreement on what should actually be monitored. For example, the establishment of performance targets with effective measures is essential to achieving policy goals such as sustainable development and the MDGs, but there is often uncertainty about what data items will best serve this purpose.

There are also substantial technical and financial constraints because of the need to measure even simple parameters such as flow, especially in difficult to access areas. Decision-makers are sensitive to the immediate costs of observing networks installation, operation and maintenance, that they perceive as not bringing immediate benefits and competing for limited funds with basic water supply, while they are rarely aware of the benefits and financial returns that increased knowledge on water resources brings to the economy of the country as a whole.

One important yet underused resource is remote sensing. As yet, it has not resulted in a significant flow of useful processed information about water and its use. And while remote sensing may prove to be a useful tool, it will never substitute the need to gather local information. Strengthening hydro-met networks and services is a necessary condition for proper water resources management, planning, design and operation.

Improving the flow of data and information

The most effective driver of efforts to improve the flow of information about water would be demands for information on the part of policy-makers and decision-makers in the socio-economic sectors of activity. There are, however, encouraging signs that more attention is being paid to the need to generate better data flows to support the monitoring of water resources and their use.

From a government perspective, economic policy-makers now recognize that water as a resource has an important influence on national economies, which is largely unaccounted for. As a result, there is a growing interest in water accounting in parallel with broader environmental accounting. The initiatives of the United Nations System of Environmental-Economic Accounting for Water (SEEAW) and Eurostat are particularly significant in this regard, as are the recent efforts of the OECD.

From the perspective of business, the United Nations Global Compact's CEO Water Mandate has recognized that emerging crises in water services and water resources pose a range of risks to the private sector – as well as opportunities. The World Business Council on Sustainable Development (WBCSD) has produced a 'water tool' to help business to monitor its use of and impact on water more systematically. The Water Footprint Network similarly encourages businesses, their customers and other stakeholders to become more aware of the water content of their products and operations (Hoekstra et al., 2011).

The interest from governments and corporate water users is also beginning to be complemented by an interest from the broader public. Civil society organizations such as the World Resources Institute have included access to information about water resources in their overall programme to promote greater public access to environmental information.

It would thus appear that, after many decades of decline, the market for water-related data may be growing and becoming demand-driven rather than supply-driven. This suggests that there are now significant opportunities for the global community of water practitioners, as well as water users and the much broader community that has a stake in water, to make substantial improvements in the availability and quality of information about the resource. Moreover, the new focus on monitoring water resources is helping to raise awareness among a broader community about the current limitations of available information.

CHAPTER 7

Regional challenges, global impacts

Africa

Africa faces endemic poverty, food insecurity and pervasive underdevelopment, with almost all countries lacking the human, economic and institutional capacities to effectively develop and manage their water resources sustainably. Sub-Saharan Africa uses barely 5% of its annual renewable fresh water.

About 66% of Africa is arid or semi-arid and more than 300 of the 800 million people in sub-Saharan Africa live in a water-scarce environment (NEPAD, 2006). Access to scarce water is exacerbated by increased demand caused by growing populations, especially in urban areas, underdevelopment, and a trend towards higher living standards in some places.

Access to improved sources of drinking water supply in sub-Saharan Africa is barely 60% overall. In rural areas it grew to 47% by 2008, but has remained static at just over 80% in urban areas over the period since 1990 (WHO/UNICEF, 2010). Only 31% of the population uses improved sanitation facilities and although the proportion of the population practising open defecation is declining, in absolute numbers it increased from 188 million in 1990 to 224 million in 2008 (AMCOW, 2010).

The urban slum population in sub-Saharan African countries is expected to increase to around 400 million by 2020 (UN-Habitat, 2005). Rapid growth of peri-urban slums has overwhelmed most water services providers and constitutes a major challenge to water supply and sanitation development.

From the mid-1990s to 2008 the number of persons who were malnourished in sub-Saharan Africa increased from 200 million to 350–400 million. Since the mid-1960s, agricultural production has increased by an average of less than 2% annually, while the population has risen at a rate of 3% (UNECA, 2006). Some 97% of the region's croplands depend on rainfed agriculture, which produces most of Africa's food (FAO, 2008). Africa needs to increase its agricultural output at a rate of 3.3% a year if it is to achieve food security by 2025.

Because irrigated cropland accounts for only 20% of its irrigation potential (and in all but four countries of the region, less than 5% of the cultivated area is irrigated) there is considerable scope for expanding irrigation to increase food security (UNEP, 2010*b*). However, there is even greater scope for expanding rainfed agriculture, harvesting water runoff and wisely using large untapped groundwater reserves that exist in some areas (UNEP, 2010*b*).

Only one person in four in Africa has electricity. Electricity provision is often unreliable as a result of a lack of investment, growing demand, conflict, unpredictable and variable climatic conditions and aging infrastructure – all of which hampers economic activity. Hydropower supplies a third of Africa's energy, but it is underdeveloped. Africa has enough hydropower potential to meet the entire continent's electricity needs, but only 3% of its renewable water resources are exploited for hydroelectricity (UNEP, 2010*b*).

Many water bodies and ecosystems are polluted with microbiological organisms from indiscriminate disposal of excreta, impairing human health through water-borne and water-related vector-borne diseases, such as malaria, diarrhoea, cholera, trachoma and schistosomiasis.

Drought in sub-Saharan Africa is the dominant climate risk. It destroys economic livelihoods and farmers' food sources and has a major negative effect on GDP growth in one-third of the countries. Floods are also highly destructive to infrastructure and transportation and flows of goods and services. They contaminate water supplies and increase the risk of epidemics of waterborne diseases.

There is a general recognition of the need to boost finance for water infrastructure across Africa. The Africa Infrastructure Country Diagnostic (AICD) (Foster and Briceño-Garmendia, 2010) estimates that US$22 billion is needed annually for the water supply and sanitation sector to close the infrastructure gap, meet the

MDGs and achieve national targets in Africa within ten years. The AICD report also estimated the potential investment needed for irrigation systems in Africa to be approximately US$18 billion for small-scale irrigation systems and US$2.7 billion for large-scale systems over a 50 year investment horizon.

Virtually all sub-Saharan African countries share at least one transboundary river basin. Water interdependency is accentuated by the fact that high percentages of total flows in downstream countries originate outside their borders (UNECA, 2000). Lack of complete, reliable and consistent data about transboundary water resources, especially groundwater, is a challenge to transboundary water management and creates a potential for conflict. African nations have also begun to seek ways to address transboundary water issues related to hydropower development, especially by fostering regional integration through power pools such as the South African Power Pool (SAPP) and the West African Power Pool (WAPP). Using such pools, countries can reduce their costs while maintaining their own power supply, rely on mutual help when power systems break down, enjoy social and environmental benefits, and strengthen cross-border relationships (UNEP, 2010*b*).

The Africa Water Vision 2025 has been adopted by African governments, the New Partnership for Africa's Development and the African Union. This is evidence of a new focus on water and, potentially, better-targeted investment and more efficient water management. Africa Water Vision 2025 calls for enhanced institutional frameworks for the strategic adoption of the principles of IWRM. Most African countries have adopted IWRM as the basis for water governance and management. International water policy recommendations continue to play an invaluable and decisive role. Far-reaching economic reforms adopted across the continent have begun to yield positive results in many countries. Negative trends in GDP have given way to progressively increasing growth, averaging around the mean figure for developing countries. In the ten years up to 2010, six of the world's ten fastest-growing economies were in sub-Saharan Africa (*The Economist*, 2011). Nevertheless, average per capita GDP growth in Africa remains far below all other regions.

Europe and North America

More than 1.2 billion people live in Europe and North America, with the latter representing just over one-third of the total. Although Central Asia and the Caucasus have experienced considerably higher growth rates between 1960 and 2000, populations are stable or declining in most countries of Western and Central Europe (PRB, 2008).

While in Canada total water withdrawals have been rising steadily over the past several decades (CEC, 2008), they have been relatively constant in the USA since the mid-1980s despite continued population growth (National Atlas of the United States, 2011). Total water abstraction has also been decreasing in most Western European countries (EEA, 2010). Despite the marked transition to a post-industrial economy, demand for water is likely to remain high in Eastern Europe, Central Asia and the Caucasus because of the dependency on agriculture, mining and other export commodities. Europeans and North Americans consume a considerable amount of virtual water embedded in imported food and products.

Modern pollution abatement technologies have stemmed the most egregious pollution from large industrial processes in Western Europe and North America, where there is a long history of environmental legislation (including water management). Although most point source pollution from industrial and urban sewage has been addressed, recent concerns are growing over modern chemicals, including pharmaceuticals and hormones. Small and medium-sized industries and small urban wastewater treatment plants in Eastern Europe, the Caucasus, Central Asia and several of the new European Union (EU) countries, which do not operate according to standards, are still important sources of pollution.
Nutrients from agricultural runoff, however, are of growing concern throughout the region. Agrochemicals have had a detrimental effect on water resources as nitrogen, phosphorus and pesticides run into water courses and percolate into groundwater. In some river basins, particularly in Central Asia, irrigation has led to soil salinization and high levels of mineral salt in water bodies (UNECE, 2011).

Since the 1960s, land under irrigation has doubled in Canada, and has increased by more than 50% in the USA, with much of the growth in arid or semi-arid regions. In many parts, groundwater levels are declining as withdrawals exceed recharge (CEC, 2008).

Some 120 million people in the European region do not have access to safe drinking water. Even more lack access to sanitation, resulting in the spread of water-related diseases. In North America, native peoples are often ill-served by piped water and sanitation facilities. For example, over 10,000 homes on reserves in Canada have no indoor plumbing, and the water or sewerage systems in one reserve in four are substandard (UNDESA, 2010).

Climate change is expected to bring higher temperatures, drought, reduced water availability and lower crop yields to southern Europe, the Caucasus and Central Asia. Hydropower potential and summer tourism are also likely to be affected. In Central and Eastern Europe, summer precipitation is projected to decrease, causing higher water stress. While climate change is likely to have positive effects in the short term in Northern Europe, these are expected to be outweighed by negative effects as climate change progresses (UNECE, 2009).

Throughout the region, structural modifications to watersheds have altered natural flows, disrupted or destroyed wildlife habitats and ecosystem services, and disconnected rivers from their flood plains – and so increasing the risk of floods in many places.

Institutional and strategic responses to manage water issues have a relatively long history in the region. In North America, water governance was strengthened in the 1970s with the passing of regulations such as the Clean Water Act and the Safe Drinking Water Act in the USA, and parallel legislation in Canada, including the Canada Water Act.

Water-related institutions in countries in transition are still generally weak (as opposed to sector-specific institutions that can be highly influential despite their more narrow focus), with water competences spread among agencies with weak enforcement capacities. Supported by the EU on many fronts, new EU Member States have made better progress in building new institutional structures in comparison with other eastern European countries, the Caucasus and Central Asia (UNECE, 2010). The Water Framework Directive (WFD), which was concluded in 2000 apart from some more recent directives on standards and groundwater, is the most important piece of EU water legislation (EC, 2000).

The use of transboundary waters, and their protection, are governed by the 1992 UNECE Water Convention. This requires parties to enter into specific bilateral or multilateral agreements and to create joint institutions. The EU Water Framework Directive has accelerated and deepened a historical process of transboundary water management across the EU's 40 international river basins, exemplified in the Danube and Rhine river basins (EC, 2008). Canada and the USA have been leaders in the bilateral management of shared waters, through the International Joint Commission in particular. Addressing transboundary groundwater issues remains an exception, as the work of many joint bodies in the area of transboundary groundwaters is still insufficient, except perhaps in some parts of Western Europe.

Asia-Pacific

Home to 60% of the world's population, the Asia-Pacific region possesses only 36% of its water resources (APWF, 2009). The region is undergoing rapid urbanization, economic growth, industrialization, and extensive agricultural development, affecting the region's capacity to meet its socio-economic water development needs. Between 1987 and 2007, the region's population grew from just under 3 billion to about 4 billion people (UNEP, 2007).

The region includes India and China, two of the most populous and fastest growing economies of the BRICS countries. Since 2000, the Asia-Pacific's annual GDP growth rate has surpassed 5% (UNEP, 2007). Growing industrial activity is accompanied by the intensive use of water resources that exert considerable pressure on aquatic ecosystems, which continue to deteriorate. The Asia-Pacific's socio-economic development pattern previously relied primarily on cheap natural and human resources. The consequences have been two parallel economies: rapid advances in economic performance alongside persisting poverty and environmental degradation. The region is attempting to reverse unsustainable consumption and production patterns by embarking on a greener development path.

Internal migration and urbanization are driving the rise in the number of megacities (UNESCAP, 2011). The region has some of the world's fastest-growing cities and between 2010 and 2025 a predicted 700 million people will be added to the growing numbers requiring drinking water supply and sanitation services (UNESCAP, 2010*a*).

There is unequal access to drinking water and sanitation services throughout the Asia-Pacific region. This includes stark contrasts between urban and rural areas, and between rich and poor households – with sanitation being the most striking disparity. About 480 million people still lacked access to improved water sources in 2008, while 1.9 billion still lacked access to improved sanitation.

Even when access is established, natural disasters and functionality levels can significantly influence whether or not drinking water and sanitation systems can continue to respond to the region's needs. The Asia-Pacific is the world's most vulnerable region with respect to natural disasters. Much economic growth is generated in coastal and flood-prone areas, which are especially vulnerable to typhoons and rainstorms. The Pacific's small island developing states are particularly vulnerable to environmental natural hazards such as tropical cyclones, typhoons and earthquakes turning into disasters. Climate change is expected to increase the magnitude and frequency of floods and droughts, and will further exacerbate the vulnerability of small island developing states (and other low-lying coastal areas) with anticipated sea-level rise.

On average, agriculture accounts for average about 80% of the region's freshwater withdrawals and is facing the challenge of increasing food production in degraded ecosystems (APWF, 2009). The irrigation sector is generally inefficient, and demand-management mechanisms are often ineffective even where they exist. Food security is a challenge for many areas in the Asia-Pacific region – 65% of the world's undernourished people are concentrated in seven countries, five of which are in the Asia-Pacific region: India, Pakistan, China, Bangladesh and Indonesia (APWF, 2009).

Water quality suffers from the impacts of industrial development, urbanization, and agricultural intensification (APWF, 2007). The ecological carrying capacity of the Asia-Pacific region is affected by deteriorating water quality, with even relatively water-rich countries (such as Malaysia, Indonesia, Bhutan and Papua New Guinea) facing urban water supply and quality constraints. Domestic sewage is a particular concern because its untreated discharges affect ecosystems near densely populated areas. Approximately 150 to 250 million cubic metres per day of untreated wastewater from urban areas is discharged into natural water bodies or leached into the subsoil.[3]

The many threats to water resources in the Asia-Pacific region reveal a complex picture and raise many concerns. These water 'hotspots' (Figure 7.1) include areas of water scarcity, lack of access to water supply and sanitation services, water quality issues, and exposure to water-related hazards.

Water infrastructure in the Asia-Pacific region is shifting from predominantly short-term benefit planning and development, to a more strategic and long-term benefit planning concept that also addresses ecological efficiency in economic development. Governments are seeking to facilitate the creation of market conditions for developing sustainable and eco-efficient water infrastructure for better provision of water services in three different contexts: eco-city development programmes for addressing urbanization challenges (urban river rehabilitation, modular water treatment design, integrated storm-water management, decentralized wastewater treatment, and water re-use and recycling); in rural areas (modern irrigation systems, decentralized drinking water and sanitation services, water reuse and re-cycling, and rainwater harvesting); and by cleaning the region's waterways through a 'wastewater revolution' (for which treating wastewater for re-use is an essential consideration). Current technology for small, compact wastewater treatment plants has improved, offering advantages over larger, centralized systems.

Water resources management in the Asia-Pacific region appears to be shifting from a supply-oriented to a more demand-management approach, but this shift faces continuing challenges. Although the implementation of demand-management measures has been uneven across the region, interest in improving water-use efficiency continues to grow.

Latin America and the Caribbean

More than 8% of the world's population lives in the Latin America and the Caribbean (LAC) region – some 581 million people – with half of them in Brazil and Mexico (UNEP, 2007).

The LAC region is basically a humid region, although it contains some very arid areas. The pattern of water use in the region is spatially sporadic and highly concentrated in relatively few areas. Approximately one-third of the population in the region lives in arid and semi-arid areas. Northern Mexico, North-eastern Brazil, coastal Peru and northern Chile, among other areas, have great difficulty in meeting their water needs. The IPCC (2008) expects that with climate change, the number of people living in water-stressed river basins will increase to between 79 and 178 million in the 2050s.

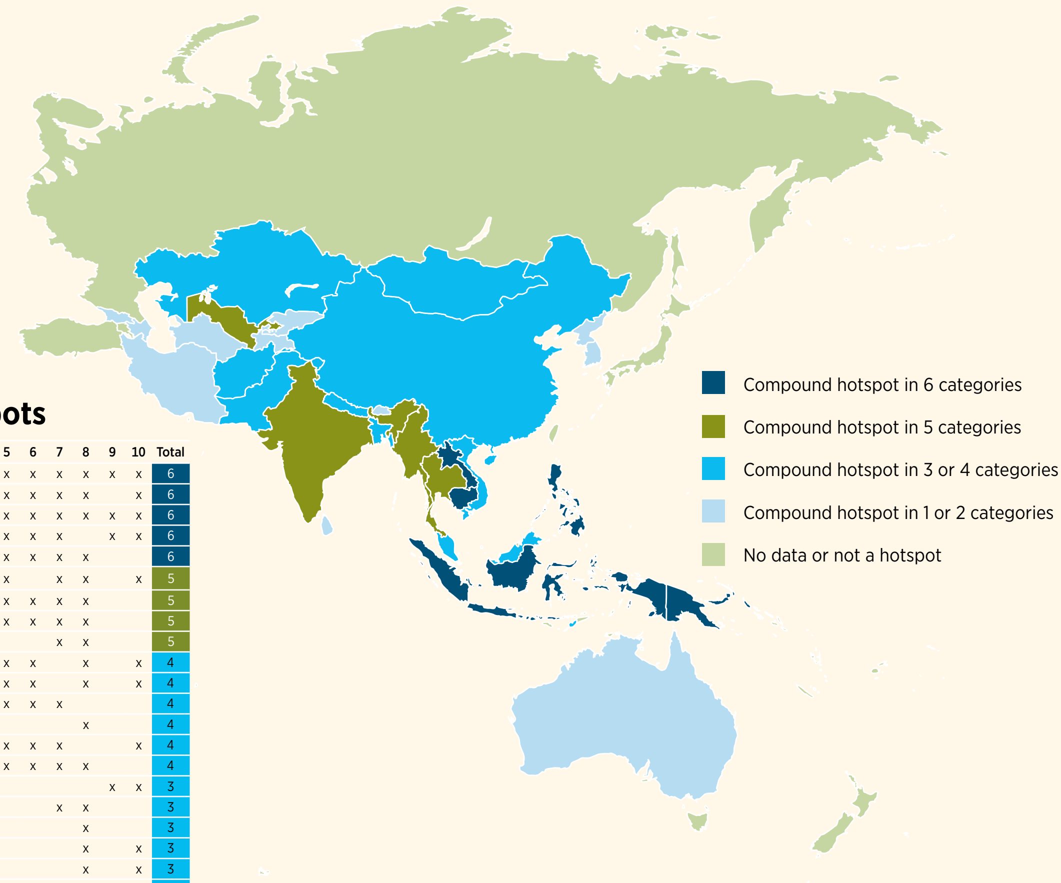
Latin America and the Caribbean is the world's most urbanized developing region; more than 80% of the population lives in towns and cities (UNECLAC, 2010). The urban population has tripled over the past 40 years and is expected to grow to about 610 million by 2030 (UNEP, 2010c). Population growth in medium-sized and small cities is a recent trend.

New demands for water have arisen from changes in both LAC societies and the global economy. This is particularly the case for tourism in the Caribbean and that for energy almost everywhere, both of which tend to be closely related to rising per capita income (OECD, 2009). The emergence of a larger middle class has lead social and political pressure to resolve environmental conflicts. However, poverty remains an unresolved issue throughout Latin America and most of the Caribbean.

With the exceptions of Mexico and some of the small countries of Central America, the countries of the region base much of their economy on the export of natural resources, particularly minerals in most Andean

FIGURE 7.1

Asia-Pacific water hotspots



Compound hotspots

	1	2	3	4	5	6	7	8	9	10	Total
Cambodia					x	x	x	x	x	x	6
Indonesia			x		x	x	x	x		x	6
Lao PDR					x	x	x	x	x	x	6
Papua New Guinea				x	x	x	x		x	x	6
Philippines	x		x		x	x	x	x			6
India	x				x		x	x		x	5
Myanmar				x	x	x	x	x			5
Thailand			x		x	x	x	x			5
Uzbekistan	x	x		x			x	x			5
Bangladesh					x	x		x		x	4
China					x	x		x		x	4
Malaysia			x		x	x	x				4
Pakistan	x	x	x					x			4
Timor-Leste					x	x	x			x	4
Viet Nam					x	x	x	x			4
Afghanistan	x								x	x	3
Kazakhstan				x			x	x			3
Maldives	x			x				x			3
Mongolia				x				x		x	3
Nepal				x				x		x	3
Pacific Islands						x		x		x	3
DPRK				x	x						2
Kyrgyzstan				x			x				2
Tajikistan				x			x				2
Turkmenistan				x			x				2
Australia							x				1
Azerbaijan				x							1
Bhutan				x							1
Georgia				x							1
Iran								x			1
Republic of Korea					x						1
Sri Lanka								x			1
Prevalence (countries affected)	6	2	5	14	15	13	17	19	4	12	

Legend

1 Increasing water scarcity threat
2 High water utilization
3 Deteriorating water quality
4 Poor water quality and low water endowment
5 Flood-prone countries
6 Cyclone-prone countries
7 Drought-prone countries
8 Elevated ecosystem/Climate change risk
9 Poor access to drinking water
10 Poor access to sanitation

Sources: ESCAP (2006, 2010a); Dilley, et al. (2005); FAO AQUASTAT database (accessed 2010).

countries, for which the global demand has increased notably in recent years, placing heavy demands on the water resources.

Water use for energy can be expected to rise throughout the region in line with economic growth. Hydropower produces 53% of the region's electricity, and installed capacity grew by 7% between 2005 and 2008 (UNEP, 2010*a*).

International demand has led to a 56% increase in mineral extraction in recent years, and despite the current slowdown in the global economy, it can be expected to continue to expand. Significant volumes of water are required for extraction and processing. Toxic waste and effluents from mining can run into water bodies, and this is one of the region's main sources of water pollution, as well as posing health and safety risks for local populations and other economic activities (Miranda and Sauer, 2010).

Agricultural demands will also increase but at much slower rates. Around 14% of the region's cultivated area is under irrigation (FAO, 2011*b*) and irrigation has expanded steadily since the 1960s. Given the intention of a number of countries in the region to play a major role in satisfying increased global demands for food and biofuels, irrigation will need to become more water-efficient.

Overall, the region is doing well in providing improved water supply and sanitation for its urban populations, but is doing much less well for its rural populations. However, many cities still have substandard drinking water supplies and sewerage networks. Often, the poorest and most vulnerable people end up paying the most for water, as they depend on expensive but often poor-quality water purchased from tank trucks (UNEP, 2010*a*).

By 2008, improved water supply was available to 97% of the urban population and 80% of the rural population – 86% and 55% in the case of sanitation (WHO/UNICEF, 2010). These aggregate statistics, however, hide significant variations in the quality of the services.

The recurring issue of under-financing of water supply and sanitation services has resulted in lack of maintenance and low levels of operating efficiency. It is estimated, for the region as a whole, that at best only a quarter of sewage is treated before discharge (Lentini, 2008), leading to serious contamination of water courses, including the sea, from both sewage outfalls and industrial discharges from urban areas.

The greatest challenge for water management in LAC is to continue to improve overall governance and strengthen management and regulatory capacity, a fact which governments are aware of (Comunidad Andina de Naciones, 2010). Responding to these challenges requires institutional arrangements for effectively protecting public interest; defining and enforcing water use rights and discharge permits; setting standards, control and inspection mechanisms; and mobilizing significant financial resources. There have been a number of interesting experiences in the region over the past few decades in the establishment of water authorities outside sectoral ministries, as well as in the creation of river basin agencies and independent water utility regulators (Jouravlev, 2004).

Reform of water laws is being discussed in most countries, but in practice, innovations are slow to materialize under real-world conditions. In many cases, reforms have failed to take account of the structural limitations of national economies as well as of sound principles in the area of public interest, economics of service provision and public utility regulation, and so have not met expectations. Several countries have reformed their water legislation (Chile and Mexico) or adopted a new one (e.g. Honduras, Nicaragua, Paraguay, Peru, Uruguay and Venezuela). Embracing IWRM in virtually all cases, some countries have recognized the right to water (among others, Bolivia, Honduras, Nicaragua, Uruguay and Venezuela) or have set up mechanisms that improve the affordability of water services by creating subsidies for the poor (e.g. Argentina, Chile and Colombia). As for private sector participation, regional experience indicates that it is not the magic formula for addressing the multiple problems that affect the provision of water supply and sanitation services.

Arab and Western Asia region

The Arab region has experienced a rapid population increase, and this trend is likely to continue. The total population in 2010 was more than 359 million, and it is expected to reach 461 million by 2025 (UNESCWA, 2009a). Over 55% of the population lives in urban areas, with rural to urban migration trends being observed in several countries (UNDESA, 2007).

Nearly all Arab countries can be characterized as water-scarce. The region's non-renewable shared aquifers, or 'fossil' aquifers, are being increasingly exploited, and saltwater intrusion from over-pumping groundwater makes a major challenge of managing coastal aquifers.

Pesticides and fertilizers from agricultural runoff, post-harvest processes, garment production, and domestic sewage are also contaminating surface water and groundwater in many areas. Pollution from oil production is a problem in some areas, although this is associated primarily with marine ecosystems. Rapid population growth, combined with migration pressures, inadequate urban planning and regulation enforcement, and large numbers of people living close to, or at, the poverty line, exacerbate the difficulties in protecting water supply sources from contamination.

Agriculture, the primary source of water stress in the Arab region, accounts for more than 70% of the total water demand in most countries (FAO, 2011*b*). The region is unable to produce sufficient food to feed its populations, with the United Nations Economic and Social Commission for Western Asia (UNESCWA) members importing 40% to 50% of their total cereal consumption (UNESCWA, 2010).

The management of freshwater resources is further complicated by the fact that many major rivers in the region are transboundary. An estimated 66% of the Arab region's available surface freshwater originates outside the region. Subnational and local-level water conflicts can also exist between administrative districts, communities and tribes.

Cyclical conflict has characterized the Arab region for decades, generating large numbers of internally displaced persons. It has also caused increased regional migration and has strained water resources and services in areas receiving the displaced populations. Urban area water demands have also increased because of migration associated with economic development, and influxes of people displaced by regional conflicts.

Lack of consistent and credible water resources data and information is hindering informed decision-making in the region. It also prevents the development of coherent and cooperative policy frameworks for transboundary water resources management and for assessing changes and progress. The difficulty of narrowing the gaps in the knowledge base rests to a large degree with political sensitivities and the national security concerns that are sometimes tied to this information.

Price increases in the global cereal market over the past few years, combined with unstable supply, also threaten food security, particularly since some countries are buying half or more of their cereal staples from abroad. Growing commercial biofuels competes with food crops for already scarce water resources in the region (UNESCWA, 2009*b*).

There has been a shift in Arab food self-sufficiency policies towards a broader concept of food security, with governments that have the available financial resources able to pursue alternative measures within the global marketplace to achieve their food needs. Still others are re-examining their development and trade policies. Long-term leasing of agricultural lands in other countries has emerged as a tool for overcoming domestic agricultural production problems arising from water, land, energy and technological constraints, resulting in reduced food security risk. Putting such efforts into operation, however, has proven controversial, especially where indigenous communities and pastoralists have traditionally used the leased lands.

The 'Arab Spring' that started sweeping through the region in December 2010 can offer opportunities to revisit water governance structures and facilitate greater consultation at the community level. Soon after the respective regime changes, government officials in Tunisia and Egypt, for example, sought to foster greater public participation at the local level in water-related planning and decision-making.

Recognizing the need for a common approach to improving water resources management and achieving sustainable development, the Arab Ministerial Water Council adopted the Arab Water Security Strategy in the Arab Region to Meet the Challenges and Future Needs of Sustainable Development (2010–2030) in 2011. Regional institutions and initiatives have been launched. In addition to promoting dialogue and capacity-building for water supply and sanitation, some of these institutions also coordinate several regional water initiatives focused on climate change, shared water resources, IWRM, MDGs and so forth.

All Arab countries have pursued supply-side approaches to address increasing water demands. This has included dam and reservoir construction, desalination and wastewater reuse, aquifer recharge, and development of new technologies to improve the efficiency of traditional and non-conventional methods such as water harvesting. Although large dams can have important negative environmental and social impacts, they also help reduce the uncertainty and risk related to floods and climatic variability.

Several countries in the region produce relatively large amounts of treated wastewater, reaching up to 9% and 10% of total water withdrawal in Jordan and Qatar, respectively (FAO, 2011*b*). Rainwater harvesting has expanded in the Arab region, and water harvesting through forest condensation is being increasingly considered. Other approaches include fog harvesting and cloud seeding. Advanced remote sensing techniques (Shaban, 2009) have facilitated the identification of underwater springs in the region, although this approach could cause territorial disputes over shared sea and submarine resources.

Regional–global links: Impacts and challenges

Water challenges do not occur in a vacuum – through a series of interconnected webs they affect diverse countries and communities in many ways. International pressures (through trade, foreign investment protection and other means) can help to alleviate or exacerbate local water-related problems. This interplay is likely to create a very particular dynamic of mounting inter-regional dependency.

Because much of the expected growth in water demand will occur in regions that are increasingly unable to grow their own food, there will be more pressure on neighbouring countries and other regions that are better endowed with land and water. However, poorly regulated foreign investments in lands that could be otherwise used to feed local populations, could potentially have devastating consequences on the fragile state of food security at the national level. There are also considerable negative environmental consequences as large-scale industrial agriculture requires fertilizers, pesticides, herbicides and large-scale transport, storage and distribution.

The incidence of natural disasters is increasing in most regions of the world, and frequently affects socio-economic development. Droughts, in addition to causing decreased access to water for particular communities, have significantly affected agricultural production – which in turn contributed to soaring food prices and food shortages (Krugman, 2011). The relationship between food prices and political unrest in Egypt in 2010–2011 did not go unnoticed by other Middle Eastern countries, many of whom have been purchasing larger supplies of wheat on the world market to limit soaring prices. This clearly demonstrates the link between drought-based food shortages and larger socio-political impacts.

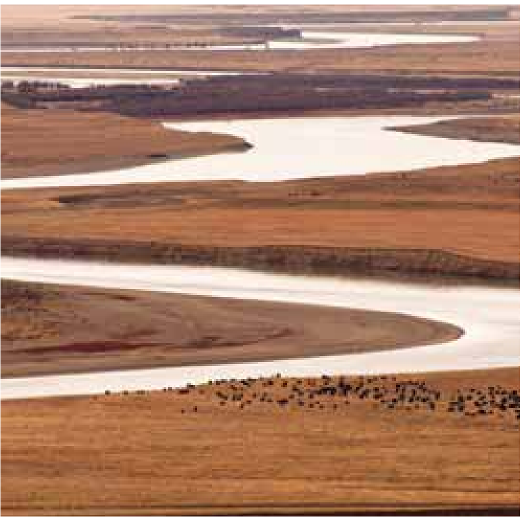
Water shortages can also cause conflicts of varying intensities and scales. Although conflicts may appear localized, they present challenges to the broader context of peace and security at regional and global levels. Water has never been the sole cause of a major war, but it could be a contributing factor, and nation states as we know them have also never experienced the kind of water shortages and conflicts that are anticipated. Where water is scarce, it can be viewed and interpreted as a security threat (Gleick, 1993). In today's global security context, no region is truly immune to conflict or strife in another transmitted through the water–energy–food nexus.

Economic and trade policies can play a crucial role in promoting the sustainable use of water resources. The question that arises is which sort of policies are best suited to ensuring sustainable outcomes at national, regional and global levels. There is a tendency towards protectionist policies that protect national or regional resources, particularly as water becomes scarcer and more valuable. On the one hand, enacting protectionist policies can create a situation where water-poor regions cannot afford products that have high water footprints. On the other hand, allowing access to foreign investors (protected by international investment protection treaties) can also be a huge risk, especially for countries with weak water management institutions that can not regulate the use of their own water resources. Another major challenge is that countries attach different valuation to water (the value of water is place- and case-specific, and often depends on supply and demand conditions) and it is therefore nearly impossible to address water valuation with a common understanding (Langridge, 2008).

As water scarcity becomes a pressing issue, synergies will have to be sought in different sectors. Water will not only have to be addressed by sustainable development or poverty alleviation schemes, but will have to be integrated more substantially into international cooperation, development, trade, diplomacy, security, and migration efforts.

PART 2

Managing Water under uncertainty and risk



Global political and social systems are changing in unpredictable ways. Technology is evolving; living standards, consumption patterns and life expectancies are changing. Human populations are growing and moving to expanding urban settings. Consequently, land use and cover is changing, as is the climate. The rate of change of these events is increasing and their long-term impacts are uncertain.

Water is the primary medium through which the impact of these changes in human activity and the climate will be felt. Without proper adaptation or planning for change, hundreds of millions of people will be at greater risk of hunger, disease, energy shortages and poverty due to water scarcity, pollution and/or extreme water-related events.

As an input to all economic activities, water will be affected by decisions made in a wide range of sectors and domains, which typically have no direct engagement with water policy. Risk will be managed in different ways in each sector or domain. Providing decision-makers with tools that show the broader water resources consequences of alternative ways forward will substantially contribute to better overall management of the resource, with the possibility of reducing adverse impacts and conflicts.

CHAPTER 8

Working under uncertainty and managing risk

Concepts of uncertainty and risk

Those who depend on water supplies or services provided by water cannot be certain that they will always have the water they need or want, or freedom from water-related hazards.

Risk and uncertainty are inherent in the decisions which water managers and policy-makers must take, and the emerging range of drivers and impacts often lie outside the traditional water arena. The more these risks are understood, the more robustly and resiliently water systems can be designed and managed to reduce the impact of future variability.

Hydrological risk is simply the product of magnitude of event and frequency of occurrence. The distribution of a hydrological time series is known and the risk of an event can be calculated with standard statistical methods on the assumption that the statistical parameters describing hydrological behaviour are adequate 'descriptors' (Faurès et al., 2010).

The most widely held meaning of *uncertainty* refers to a state of mind characterized by doubt, based on a lack of knowledge about what currently exists or what will or will not happen in the future. It is the opposite of certainty, which is a conviction about a particular situation. Uncertainties increase the further one looks into the future. Nevertheless, everyone making decisions that will impact future events needs informed judgments about plausible futures, even though they are uncertain.

Historically, water planners and engineers have been able to base their decisions on characteristics of the water cycle and hydraulics which could be described within known statistical parameters and stable probability distributions. Today, these professionals are having to deal with future probabilities of trends and events that are outside the envelope of variability defined by past events – including rapidly evolving drivers of water demand and increasing climatic variability. As water is an input to all economic and social activities, decision-makers need planning tools which reflect the wider consequences of their decisions over the long term.

How uncertainty and risk affect decision-making

When faced with a problem or decision that involves risk, managers can either accept the risk or attempt to reduce it before making the decision. Ways of reducing risk include conducting further analyses and collecting more information. In some cases, such as for hedging against incurring flood damage, it might be possible to buy insurance. This transfers some of the risk to a third party, reducing the consequences of a risk.

Informed decision-making is increasingly becoming a bottom-up process. Where risks and uncertainties prevail the experts have no monopoly on what might happen in the future or what might be sustainable. Everyone's opinion is needed, especially the impacted stakeholders, who can determine the success or failure of any decision. IWRM, by definition, involves the participation of all interested stakeholders. Interactive decision-support models have been developed and successfully used to facilitate stakeholder participation.

Two approaches for dealing with the extremes of uncertainty now encountered in complex water management problems are adaptive strategies and robust strategies. An *adaptive strategies approach* selects plans that can be modified to achieve better performance in the light of realized outcomes. These strategies can be responsive to new goals or objectives of system performance as well as to changing inputs over time. Robust strategies identify the range of future circumstances, and then seek to select approaches that will work reasonably well across that range. This applies especially to decisions that cannot be easily or cost-effectively modified in the future.

Scenario analysis is also an appropriate and tested approach for dealing with uncertainty. Analysing water issues in the context of sustainable development requires a long-term view that takes into account the evolution of some of the hydrological and social processes involved. Scenarios are hypothetical sequences of events, constructed for the purpose of focusing attention on causal processes, decision points and the unfolding of alternatives – and to branching points at which human actions can decisively affect the future. They are particularly helpful in situations where it is difficult to assign probabilities to possible events or outcomes, whether due to a limited initial understanding of the processes involved, or due to the intrinsic indeterminism of complex dynamic systems.

"Scenarios are hypothetical sequences of events, constructed for the purpose of focusing attention on causal processes, decision points and the unfolding of alternatives – and to branching points at which human actions can decisively affect the future."

Using ecosystems to manage uncertainty and risk

History shows that pressures on water resources decrease ecosystem resilience and thereby increase ecosystem-related risks and uncertainties. Water-related ecosystem infrastructure involves all biological/ecological components of the water cycle. Reducing pressures on ecosystems can serve to reduce uncertainty, help manage risk, and achieve increased benefits from water security and water quality enhancement, recreation, hydropower, navigation, wildlife and flood control.

History also shows that many risks associated with water arise through management that is blind to the ecosystem changes it drives, and their consequences for humans and the economy. Ecosystems are central to sustaining the water cycle; therefore, understanding this role provides a tool to assess how risks are generated and transferred. An inclusive, holistic and participatory approach to water policy and management permits identification of the full range of ecosystem services involved, where the risks are, and who is vulnerable to them and why.

The role of land cover (vegetation) and soil in reducing hydrological risk illustrates the need to rethink water storage in ecosystem terms. The use or restoration of ecosystem infrastructure to sustain or improve water quality is already a widespread practice with a proven track record. Using ecosystem infrastructure to manage risks associated with flooding is another area in which interest, practice and demonstrated feasibility are rapidly developing.

At the implementation level, water managers may be called upon to actively manage various elements of the ecosystem and/or to inform those who have that responsibility. Identifying opportunities to proactively manage ecosystems to reduce uncertainty and manage risk involves a three-step process:

1. Identify the water management objectives as opposed to focusing on infrastructure (e.g. objectives are water storage or clean water, not dams or treatment plants).
2. Explore what ecosystems offer in terms of meeting the identified management objective(s) (e.g. storing water, reducing pollution), including through their conservation and/or restoration.
3. Reduce the uncertainties and risks involved in decisions by considering all ecosystem services directly involved or potentially impacted by various management options. This includes valuing multiple co-benefits, and examining trade-offs between them to determine desirable courses of action.

CHAPTER 9

Understanding uncertainty and risk associated with key drivers

Possible evolution of key drivers

Water stress and sustainability are functions of the available water resources and their withdrawal and consumption. Both resources and consumption are variables that depend on many factors. Drivers that directly impinge upon water stress and sustainability are the *ecosystem, agriculture, infrastructure, technology, demographics* and *economy*. The ultimate drivers, *governance, politics, ethics and society* (values and equity), *climate change* and *security* exert their effect mostly through their impacts upon the proximate drivers.

The United Nations World Water Assessment Programme (WWAP) World Water Scenarios Project undertook survey-based research on ten drivers of change, the relevance of which varies in different regions of the world. Participants in these surveys identified and quantified a number of the most likely drivers, summarized below.

Increased water productivity in agriculture has been ranked as the most important development affecting water. Between 1961 and 2001, water productivity for agriculture nearly doubled. Survey participants estimated that agricultural productivity would be likely to double again by 2040.

The second most important development affecting water was the *percentage of land area subject to droughts.* The participants estimated that this could increase by at least 50% for extreme events, 40% for severe droughts and 30% for moderate ones by the 2040s.

Climate change will affect the hydrological cycle and hence the availability of water. Project participants estimated that the number of people at risk from water stress was likely to reach 1.7 billion before 2030 and 2.0 billion by the beginning of the 2030s. A 50% increase in delta land vulnerable to serious flooding is seen as likely to occur by the beginning of the 2040s.

Survey participants considered that, as a result of *infrastructure development*, 90% of the global population would probably have reasonable access to a reliable source of safe drinking water and to appropriate sanitation facilities, by the beginning of the 2040s.

The widespread adoption of *rainwater harvesting*, combined with simple and cheap ways of purifying the collected water, was also considered a likely development between 2020 and 2030. Better use of *affordable technology* by agriculturalists to check crops and soil moisture will also increase the efficiency of irrigation schedules.

Population estimates put overall world population size at almost 8 billion by 2034, 9 billion by the beginning of the 2050s and over 10.5 billion beyond this. Population growth could overwhelm past gains in water and sanitation accessibility, particularly in developing countries where recent improvements in access to water supply and sanitation could be more than negated.

Education and employment of women was seen as a development influencing fertility, particularly in least developed countries. By the 2030s, the rise in levels of women's education and employment in a majority of least developed countries could cause a significant decline in fertility levels.

Growth in urban population was also deemed important. By the end of the 2030s 70% of the world population was seen as likely to become urban. The proportion of the world population living in slums was likely to decrease just to 25% by the end of the 2040s, from 33% today.

The *demand for water* in developing countries could increase by 50% over the 2011 level. Over 40% of countries, mostly low-income ones or located in regions in sub-Saharan Africa and Asia, could experience severe freshwater scarcity by 2020. An important risk is that unequal access to water will create new economic polarities and give rise to political tensions.

In terms of *governance*, the development of online forums on water issues, including local government and civil society, could help reduce the asymmetry of information between user, provider and policy-makers. Networked coordination at the national level to share information and best practices between local water agencies could be achieved in at least 95% of countries between 2020 and 2030. However, it is important that governments should be able to respond to these information flows. There is a concern that resistance from government and vested interests could prevent the necessary flexibility, participation and transparency of governmental policy-making.

The survey participants on *politics* had similar views on the importance of establishing and following transparency and participation procedures in matters of water governance. However, they saw little likelihood that this would take place in at least 120 countries by 2020–2030.

"The likelihood of changes in precipitation patterns and increased variability of future water supply, as a result of climate change, will make analyses based on historical data less reliable."

A shift in human values, whereby people agree that the present has an obligation to preserve opportunities for the future, was deemed likely within the 2020–2030 timeframe by the survey group on *ethics and culture*. The deepening of current inequalities in access to water in poor countries caused by increasing water scarcity was also deemed likely to occur over the same period.

Responding to the challenges: The past is a poor guide to an uncertain future

Traditionally, the statistical analysis of past climatic records has been a fairly reliable basis for predicting the water cycle and its hydrological extremes. However, the likelihood of changes in precipitation patterns and increased variability of future water supply, as a result of climate change, will make analyses based on historical data less reliable. There is also greater uncertainty on the demand side due to an increase in the number and complexity of choices, which are outgrowing managers' abilities to assimilate and analyse data and make decisions.

The timescale for agreement on solutions and their implement can stretch to decades, especially for issues with a regional or international dimension. The pace of change reduces the time available for recognizing the problem and agreeing and implementing the right decisions at the right time. Decision-makers outside the 'water box' are themselves affected by the uncertainty of how shaping forces will evolve. Water managers can only inform their decisions and manage with the available tools. In this context, it is important to develop relevant information as close as possible to the geographic scale at which they work. Figure 9.1 illustrates the multiplicity of drivers and the complex interactions between them.

Scenario analysis is a planning tool for assessing responses to a potentially very different future, depending on how different key drivers develop and interact. Because it is rarely possible to consider all of them simultaneously, scenario analysis takes a limited number of drivers at a time, and assesses their combined influence on shaping the future. Sensitivity analysis is undertaken for drivers not included explicitly, to confirm the validity of the scenarios that have been generated. These projections may then be used in the evaluation of policy and planning responses, to maximize benefits and/or minimize losses in achieving the desired state. The next phase of the WWAP World Water Scenarios Project will entail developing scenarios and scenario-development tools that can be used by decision-makers.

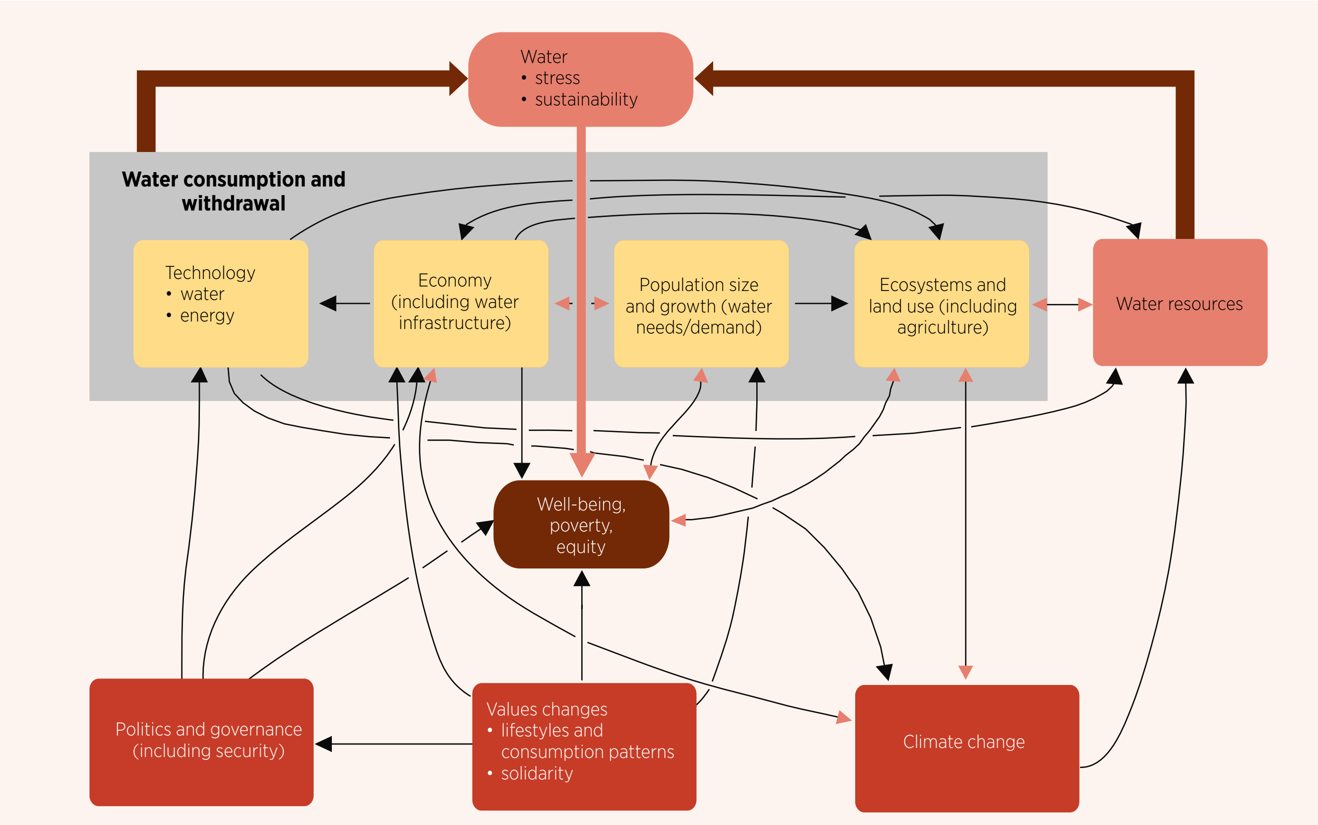
Peering into possible futures

Even without the benefit of the systematic and analytical approach employed in the World Water Scenarios project, it is useful to consider how certain drivers could interact with each other, and how the trends cumulate in order to examine possible futures for water resources.

In one possible future, the status quo continues, without further intervention. Growth in food demand resulting from population growth and changes in nutritional habits, combined with increased urbanization, lead to a greatly increased demand for water. Expanding human settlements will encroach on fragile or marginal lands, and there will be increased deforestation and pollution. Climate change is expected to result in decreased water availability in many regions, exacerbating economic polarities between water-rich and water-poor countries, as well as between sectors or regions within countries. Much of the burden of these impacts is likely to fall on the poor.

FIGURE 9.1

Key drivers and causal links affecting water stress and sustainability and human well-being



Source: Gallopín (2012, fig. 2, p. 8).

A second possible future is one in which technological advances are fully exploited, particularly the trend towards desalinization. Technological developments in agriculture lead to sizeable water conservation. Other technological developments in urban water production and waste handling also contribute to reducing absolute water withdrawals and waste. Rapid uptake of these technologies would be paired with an increased popular appreciation of water scarcity.

A third possible future extrapolates current demographic and technology trends, and includes a set of policy interventions that could be adopted over the next two decades. A legally binding international agreement to combat climate change could be in place by 2040, along with significant financing for awareness-raising and adaptation in low-income countries. Because most climate change impacts are felt through water this would have positive repercussions on the overall levels of financing for water. This could mean high levels of investment in water infrastructure, leading to reductions in waste and increases in sustainable mobilization, as well as increased sewerage network coverage.

Several other policy interventions are considered in this third scenario. Investment in water management and conservation, as well as sanitation, is expected to have multiple poverty-reduction benefits, based on development of solid property regimes, documented land tenure arrangements, and clearly established water rights and allocation systems. Subsidies that encourage inefficient uses of land, water and fertilizers, creating a bias in favour of high water users, would be gradually replaced by flexible, index-based insurance schemes that allow producers to make short-term cropping decisions based on climate variability and extremes. River basin institutions and decentralized authorities would be given increased power and resources to effectively manage water within countries. This would promote local and climate-responsive allocation of water among users, facilitation by well-regulated pricing and innovative water rights trading mechanisms.

Water futures for better decision-making

Exercises in future thinking provide a cursory view of potential futures and an illustration of the interconnections between the various drivers. They illustrate the possible impacts of a set of strong policies and choices that may appear difficult (or risky) today, but are most likely to yield rapid economic and livelihood benefits at all levels and reduce long-term risks and uncertainties.

> "Targeted and relevant knowledge is necessary to make informed 'no-regrets' policy decisions, whether at the international, national or local level."

However, more concrete, rational and scientific modelling of water futures is necessary to better calibrate and explore these possible futures, including the development of regional and global water scenarios. Knowledge, or its lack, is one of the key limitations to adopting some of the measures noted above. Targeted and relevant knowledge is necessary to make informed 'no-regrets' policy decisions, whether at the international, national or local level. Knowledge reduces uncertainties and makes risks more manageable at the individual, community and international level.

CHAPTER 10

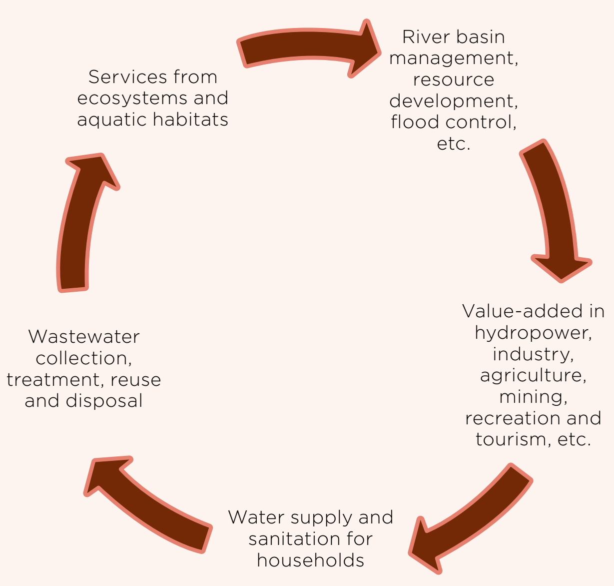
Unvalued water leads to an uncertain future

The political economy of investing in water: Stating the benefits

Given that increasing pressures on water resources are leading to a shortage of water to satisfy all needs, choices must be made about how to share, allocate and reallocate increasingly scarce water within sectors, from one user group to another, or between sectors such as agriculture, industry, mining, energy and tourism. Valuing the many socio-economic benefits of water is fundamental to improving the decisions of governments, international organizations, the donor community, civil society and other stakeholders. An appreciation of the economic value of water in its different states and uses is a necessary part of effective water management. In the absence of proper valuation water is prone to suffer political neglect and mismanagement. In turn this leads to suboptimal levels of investment in water infrastructure and to the low priority given to water policy in country development programmes, poverty reduction strategies and other policies.

FIGURE 10.1

Benefits from the water cycle



Although water is often misleadingly referred to as a sector, it is actually a ubiquitous medium, and one that creates benefits at each part of its hydrological cycle (Figure 10.1). The many facets of water can also be viewed as a *value chain* (OECD, 2010a).

Water is increasingly a critical factor in decisions regarding the location of economic activities such as industry, mining, power, export-oriented agriculture and tourism. Companies working or contemplating investment in water-stressed regions are becoming aware of their 'water footprint' and its impact on local communities, which could pose operational and reputational risks to their business or generate conflicts.

The most visible and best-studied aspect of the water cycle concerns household services – the benefits to individual people and their families from receiving clean, safe water and associated sanitation in a reliable fashion or close to where they live. People receiving such services are at less risk of contracting waterborne disease, spend less time fetching water and less money buying it, and have more time and energy available for personal washing, cooking and domestic cleaning. Likewise, improved household sanitation provides numerous benefits for public health. Empirical studies carried out at the WHO and elsewhere show that investments in a range of water supply and sanitation interventions can have high economic benefit–cost ratios. The benefits are typically savings in time spent in household duties, including fetching water and, to a lesser extent, savings in the various costs incurred in illness and medical treatment (Hutton and Haller, 2004).

Valuing water

Valuing the multiple socio-economic benefits of water is essential to improving the decisions of governments, international organizations, the donor community, civil society and other stakeholders. Conversely, a failure to fully value all the benefits of water in its different uses is a root cause of the political neglect of water and its mismanagement.

Valuing water should facilitate water resources and services to be added or compared, or allocated to maximize social welfare. However, not all the benefits of water can be quantified or expressed in monetary terms. There are many limitations to the methods developed to derive the economic value of water in its different uses: some are controversial, have high data requirements, are complex, or require technical and economic skills. But although the production of a comprehensive system of economic values for water is an ambitious task, some useful results have been produced in specific local or regional contexts from multi-stakeholder processes involving actors with different subjective valuations.

The *price* of water is a financial or fiscal transaction between the provider and the user, which is often closely controlled and regulated by public authorities, and often bears little relation to either its value in specific uses, or its cost of supply (including the cost of the infrastructure, its operation and maintenance).

The methods of valuing water are eclectic and depend on the sector concerned, the type of use and the information available (Winpenny et al., 2010). Approaches to water valuation for consumption by households, industry or irrigation can differ considerably amongst themselves and various other valuation options can be applied to in-stream uses such as waste assimilation and dilution, flushing sediment, the functioning of ecological systems, hydropower, navigation, and different types of recreation. The value of water with regard to its environmental uses is often not adequately represented in these approaches. Failure to account for these benefits in water valuation can result in inefficient water allocation decisions.

Using benefits and values to inform water policies

A sense of the economic value of water in its different states and uses is a necessary part of water management. This is true in routine management of river basins and the operation of multi-purpose storage schemes, where decisions on allocations have to be made in real-time, day-to-day situations. It also applies to seasonal drought responses and even more so to strategic decisions on adaptation to growing water stress and supply-demand imbalances.

In well-functioning water markets, economic values will establish themselves through trading prices. Where such markets have been created, usually between farmers, prices will typically reflect the value of marginal amounts of water necessary to secure the most valuable, or water-sensitive, uses. A more complete analysis of differential water values is desirable for regulating water trading, for example when it is in the public interest to allow trading between rights holders. Using water values to inform management and allocation policies does not imply that markets should not be regulated. Public authorities need to intervene to set the rules of the game, avoid the transfer of negative externalities to the third parties, ensuring adequate supplies of water and sanitation services to satisfy basic needs and to safeguard public health.

Allocating water under conditions of risk and uncertainty

The allocation of scarce water to competing uses lies at the heart of water management. In many parts in the world, increasing pressures on water resources are leading to a shortage of water to satisfy all needs. In general, four inter-related processes drive water stresses: population growth; economic growth; increased demand for food, feed and energy (of which biofuel is one source); and increased climate variability. Choices must be made about how to share, allocate and reallocate the increasingly scarce water – within sectors, from one user group to another, and between sectors.

Water allocation embraces practices that vary greatly in scale and duration. They include: the grant of water rights or permits to large irrigation schemes expected to last for decades or even indefinitely, while effective and beneficial use continues; hourly allocation schedules between irrigators; short-term reservoir releases to cover peak demands in the electricity grid; and schedules for rationing water between industries, essential services, power generation, farmers and households in the event of drought.

> "Ideally, water allocations are the outcome of dialogue between interested stakeholders. Such parties need to build convergence in their 'value perspectives'."

There are four main aspects of a water allocation system:

- *Water entitlements* (formal or informal) confer on the holder the right to withdraw water and apply it in a generally recognized beneficial use (Le Quesne et al., 2007). A person's entitlement to withdraw water must be considered legitimate by others.
- *Water allocation* is a process whereby the available water is shared among, and distributed to, legitimate claimants according to their entitlements (Le Quesne et al., 2007).
- *Water service delivery* (or *control*) is the physical act of supplying water in such a manner that it can effectively be used.
- *Water use* is any deliberate application of water to a specified purpose (Perry, 2007).

Ideally, water allocations are the outcome of dialogue between interested stakeholders. Such parties need to build convergence in their 'value perspectives'. Effective stakeholder engagement is necessary to make water allocation decisions transparent and fair. Routine stakeholder consultation is not the same as true empowerment, where a community takes control of its water management, leading to more legitimate and cost-effective solutions with better chances of implementation.

CHAPTER 11

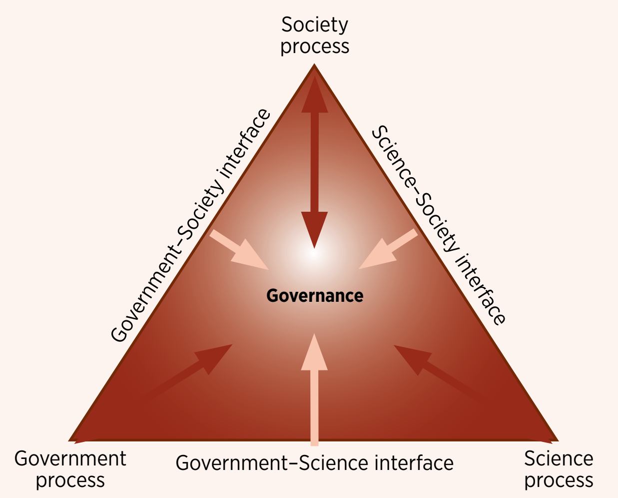
Transforming water management institutions to deal with change

Sustainable development under conditions of inherent uncertainty will require deliberate efforts to build robustness and resilience into the management structures of water projects as a matter of routine. Such fundamental changes are likely to occur in the non-structural elements of water management measures. Leaders in government, private sector and civil society outside the 'water box' take most of the important decisions impacting water. It is therefore important to develop new ways to provide specialized information to decision-makers in government, as well as to those affected by the decisions they take (Falkenmark, 2007). This requires a formal structuring of relationships between technical specialists, government decision-makers and society as a whole (Figure 11.1).

Rather than planning for one defined future, water management agencies increasingly need to improve their methods of assessment in order to respond to a range of possible futures, all of which are uncertain but present varying degrees of probability. A top-down approach, being more strategic in orientation, offers a general framework within which a water management

FIGURE 11.1

The Trialogue Model with structured interfaces between the three main actor clusters of government, society and science is conducive to adaptive IWRM



Source: Hattingh et al. (2007, fig. 1, © CSIR 2007, with permission from the copyright holders, IWA Publishing.).

activity or programme can be developed and implemented. A bottom-up approach, being more operational in orientation, can provide an accurate picture of relevant 'on-the-ground' water issues, needs and uncertainties experienced by a wide range of actors and stakeholders. Enthusiasm and support for addressing water-related issues are often best developed at the local level, as this is closest to the point of actual impact, thereby facilitating acceptance of needed actions, provided that it is adequately positioned and has the capacity to effectively deal with the issues. Developing and implementing an effective water resources management programme ideally incorporates both ends of this management spectrum, specifically as the emphasis shifts from building infrastructure to building institutions.

Approaches for managing water risk and uncertainty

IWRM needs to embrace an adaptive approach in response to exogenous changes. One way is to ask what can be done today to shape a more desirable range of possible futures: by seeking robust projects or strategies that do not require a major revision of current economic and optimization decision rules used in water resources management. Such robust strategies are revised as better information becomes available; and use computer-aided analysis for the interactive e xploration of hypotheses, options and possibilities.

It is not easy for water management institutions to adopt an integrated planning and management strategy. Many existing rules and regulations may limit the scope of responsibilities or decisions any given institution can make. Hence one question to ask to check on the degree of integration obtained by some decision by some institution is: Who is responsible for implementing integrated plans and policies? Who is responsible for making sure all possible outcomes, and drivers, and affected stakeholders, have been considered in the decision-making process? Who is responsible for looking into the future and deciding whether or not some decision will be judged as important for future sustainability? Having answers to these questions is a measure of the extent to which adaptive IWRM has been implemented.[4]

As IWRM becomes more adaptive it will involve more multi-sector and multi-disciplinary collaboration. It will also be necessary to look beyond what is traditionally considered water management and link it with decisions made in other interconnected domains such as land management, agriculture, mining and energy.

Main Message 4: Strong institutions and political will are needed to facilitate discussion and decisions between sectors and help balance risks. Institutional arrangements and regulatory frameworks must also have the flexibility to adapt to changing circumstances affecting water management.

Institutions for managing risk and uncertainty

Present-day water institutions in general are not well equipped to deal with contemporary challenges, such as integrating land and water resources management, working towards synergies, ensuring transparency and accountability, acquiring sufficient capacities and resources, and possessing adaptive capacity. Typical mechanisms to deal with uncertainty include establishing watershed services, reducing transaction costs, creating linkages across sectors, and developing a new leadership style.

Improving institutions entails fostering the capacity to work outside the 'water box' in a way not yet common in mainstream practice. Institutional capacity needs to encompass a clear definition of the roles and responsibilities of each authority, particularly in cases of emergencies or slow-onset disasters. Important features of adaptive institutional capacity are clear decision-making procedures, communication protocols and contingency planning, sustained by regular training and simulation exercises (WWAP, 2009).

Water management institutions are most effective when based on collaborative governance. Water management that builds on a joint effort of government, society and technical institutions ensures that measures will be both effective and sustainable (Hattingh et al., 2007). This entails looking outside the 'water box' and improving disciplinary integration over diverse aspects such as water, agriculture, mining, environment, planning, finance macroeconomic policies, and rural development, on both technical and policy levels. Achieving this will require the building of trust and social capital to ensure that a problem-solving process takes place (Timmerman et al., 2010).

Communicating risk and uncertainty

Uncertainties and risks involved have to be clearly understood if they are to be appropriately managed.

Without precise information expressed in a clear and concise way, the magnitude of any risk or uncertainty involved in an action is easy to misjudge. Mistakenly attaching excessive risk to events may not only cause unnecessary anxiety, but may also cause individuals to put themselves in the way of harm (Thaler and Johnson, 1990).

Another area that can cause confusion when communicating uncertainty and risk – and indeed when communicating in general – comprises the numerous different voices or opinions, expert or otherwise, that are put forward. If conflicting arguments or opinions are being expressed by what are considered to be reliable and reputable sources – such as trusted media organizations, experts, government agencies or respected personalities and journalists – the resulting situation rapidly creates confusion in the eyes of the general public.

Communicating aspects of uncertainty and risk can be a particular challenge when the nature of the decisions being debated is largely technical. The challenge is how to most effectively help the public, stakeholders and decision-makers to understand uncertainties and their impact on possible decisions, thereby enabling them to be better informed as they participate in debates over which decisions are best. One of the aims is therefore to express probabilistic information and expert opinion in transparent non-technical and recognizable terms.

It should be acknowledged by all those making estimates of, or trying to quantify, risk and uncertainty that these estimates or quantitative measures are themselves uncertain. The goal is to communicate what is presently thought, or known, as precisely as possible, and to communicate the level of uncertainty.

"Mistakenly attaching excessive risk to events may not only cause unnecessary anxiety, but may also cause individuals to put themselves in the way of harm."

Separating the audience into target groups and tailoring the communication to each can clarify and strengthen the impact of the message. A target group of high importance is the media, in all its various forms. Many crucial messages are imparted through the media, whether expressed negatively or positively. In order to motivate a target audience with targeted messages it is important to clearly define each group and understand their motivation. How each group responds to communication and acts upon its message is also likely to be different. Once the target audiences have been defined and their motivations and interests better understood, it is easier to communicate information effectively.

The media is a powerful communicating force both at local community and global levels, and influences opinions – and therefore actions – in a vast array of topics. It is important to strike a balance between attracting the media, while being aware of and taking responsibility for the possible impact of the information fed to them.

When communicating through the media or otherwise, it is important to highlight the fact that uncertainty and risk can also bring opportunity and the possibility of positive change.

Knowledge is empowering and forms the basis for making informed and progressive decisions, and information communicated in a clear and targeted way can enable people to better understand, and reach their own conclusions, about the risk involved. This in turn imparts responsibility and encourages action, which is essential for change.

CHAPTER 12

Investment and financing in water for a more sustainable future

Investing in water for sustainable development

Investment in water infrastructure, in both its physical and natural assets, can be a driver of growth and the key to poverty reduction (UNEP, 2010*d*). Although the recent global economic crisis set back investment in water in many countries (Winpenny et al., 2009), the impacts have been varied, and some governments have made determined efforts to compensate and stimulate growth and protect employment through counter-cyclical fiscal measures. Green investment in renewable energy, energy efficiency, more efficient use of materials, clean technology, waste mitigation, and sustainable use and restoration of ecosystems and biodiversity accounts for approximately 20% of the US$2 trillion of economic stimulus packages announced since 2008. Water is one of the beneficiaries of these programmes, although its full importance has not yet been recognized. Water resources management and the supply of water services must be better funded than at present.

The *green economy agenda* has serious implications for investments in water infrastructure. It increases pressure for more efficient use of resources and reductions in waste and greenhouse gas emissions, both of which aim to shift investment and consumption patterns towards alternatives that deplete less natural resources. According to the United Nations Environment Programme (UNEP) (2010*d*), water is one of 11 key green economy sectors[5]. However, compartmentalizing water as a 'sector' among others is too limiting as it fails to recognize its cross-cutting nature.

The water development agenda overlaps with the green economy agenda in the following areas: pollution control, wastewater collection, treatment and reuse, successive uses of water, water use efficiency, energy efficiency in water and wastewater treatment, distribution and reuse, energy recovery, emission mitigation (capture of methane in wastewater treatment and irrigation), irrigation, hydropower and management of natural water ecosystems (including wetlands). A large percentage of these projects target several objectives simultaneously, which can often make financing such projects easier. Water development can thus gain from the economic and financial synergies that stem from the green economy. However, other actions justified by their 'greenness' (e.g. biofuels) may pose problems for water management unless they factor in and mitigate their potential impact on water.

Funding governance, institutional reform and management

Financing will be needed not just for investments in infrastructure, but for essential items such as data collection, analysis and dissemination and to develop human resources and technical capacities. Generating data for policy-makers and managers is currently underfunded and under-provided. Supplying this information can be regarded as a public good for countries, regions and the wider international community. Investment in upgrading national water information bases to systematically report on a few key 'data items' can show good returns and are being targeted for support by international development agencies.

Adequately funded water governance is also essential for reducing uncertainty and managing risks. Effective governance in areas such as environmental controls, groundwater monitoring and abstraction licensing, and monitoring and control of pollution can reduce the risk of overexploitation of water, or of catastrophic surface water pollution and irreversible contamination of aquifers. Some of these governance functions can sometimes be self-financing through abstraction and pollution charges.

Funding for information

Data and information are a necessary adjunct to good decision-making and to reducing uncertainty. The neglect and decline of national observation systems, which have caused a loss of vital hydrological data have been addressed in Chapter 6.

Investment in the technology needed to upgrade countries' water and water-related information bases and reporting mechanisms can result in significant returns. Investment in weather forecasting and hydro-meteorological services can be highly cost-beneficial; for example, for more efficient water allocation decisions, and better infrastructure design and operation; and improved weather and flood forecasting is crucial to flood risk management and the reduction of flood-related impacts.

Funding in response to climate change and growing water scarcity

Projections reveal that the annual cost of climate change adaptation in developing countries in the industrial and domestic water supply sector would be between US$9.9–US$10.9 billion (net) and US$18.5–$19.3 billion (gross). Costs for riverine flood protection are projected at between US$3.5–$5.9 billion (net) and US$5.2–$7.0 billion (gross) (World Bank, 2010*b*).

Climate change will mainly be experienced through greater variability of temperatures and hydrological conditions. Adapting to *current* variability is an important first step in many cases. A common element of risk management, in view of the residual uncertainty about the impacts of climate change and other forces driving change, is the *no regret* criterion: a policy that would generate net social and/or economic benefits irrespective of what change occurs. Examples include demand management measures; improvements in the efficiency of water distribution; wastewater recycling; early warning systems for floods, droughts, and other extreme weather events; and risk-spreading through insurance schemes.

There is a range of development funds available for climate change adaptation and mitigation projects, some created especially for this purpose. However, much of the adaptation/mitigation effort will fall to private companies, farmers and households who cannot tap into these development funds. For them, their own resources or commercial finance will be critical. Public agencies have access to specialized climate change funds, a few of which are available for adaptation in water. At a country level there is a strong case for 'mainstreaming' adaptation as much as possible, rather than consigning it to a marginal part of the public investment programme, requiring its own procedures and criteria.

Funding diversification and demand management

Diversifying the sources of water by increasing the use of technologies, such as desalination and reclaimed water, and, when feasible, promoting self-supply by users (farmers, households and companies) can reduce and distribute risk, compared with relying on a few sources that are dependent on the same hydrological system. Some of these are easier to finance from conventional means than others. Desalination plants and certain projects for the use of reclaimed water, which entail sizeable investment in wastewater treatment plants, lend themselves to public sector or stand-alone commercial ventures funded from equity and commercial finance – typically under a form of concession contract.

Demand management needs a different approach to financing. Much of the cost of demand management falls on consumers – households, farmers and industries – and is financed largely by them, though governments can help with subsidies, tax breaks and other incentives (McKinsey & Company, 2009).

Generating finance for water infrastructure and services

All countries at every level of development face heavy costs in creating a water infrastructure that is 'fit for purpose', which can address the growing challenges and risks identified throughout the WWDR4. The global financial crisis will potentially magnify the already large investment needs (World Bank, 2010*c*). A rethinking in financing strategies is therefore required to ensure that improvement in public expenditure efficiency results in additional resources.

Generating finance for water infrastructure and services requires a pragmatic and eclectic approach. Certain types of projects, such as wastewater treatment, desalination, and wastewater reclamation and reuse potentially lend themselves to stand-alone commercial ventures funded from equity and other types of commercial finance. However, raising commercial finance for water (which has never been easy) has become more difficult due to the global financial situation since 2007, which has discouraged new private interest in water infrastructure projects and adversely affected the supply of risk capital and loan financing. Some innovative deals, developed with technical assistance and risk-sharing from donor agencies, are stalled. At the same time, though many national governments are constrained by their fiscal position, others have benefited from strong commodity prices and have used their fiscal resources to invest in infrastructure, including water. Yet other countries have 'simply' chosen to assign a high priority to water in their economic development and social strategies, to promote economic growth (e.g. Chile) and combat poverty (e.g. Peru).

Improving the collection rate of water bills is an obvious way of increasing water revenues without raising tariffs. Persistent non-payment, especially by public departments and agencies, leaves a big hole in the accounts of water authorities normally expected to be self-sufficient.

In addition to official development assistance or aid (ODA), which in the case of water and sanitation is evenly split between grants and soft loans (OECD-DAC, 2010), multilateral international development banks (World Bank, regional development banks, European Investment Bank) offering loans on attractive terms have regained some market share for infrastructure finance during the recent financial crisis, taking advantage of the absence of commercial lenders (e.g. World Bank, 2010*d*).

Since most revenues arising from water services are in local currencies, foreign exchange risk is a potential issue for water projects and providers, both private and multilateral. Hedging against devaluation risk is not a practical proposition. The more sustainable long-term solution is to generate more internal revenues form tariffs and to rely as much as possible on local financial and capital markets (Jouravlev, 2004).

Mitigating financial and political risks

Financial markets have a variety of ways of dealing with the risks for lenders and investors discussed in the WWDR4. Insurance and guarantees can 'cover political, contractual, regulatory and credit risk from both multilateral and bilateral development agencies. These guarantees have a development motive, as opposed to export credit and investment insurance, limited to firms domiciled in the country offering the guarantee, which has a commercial aim. There is also a large and active private market offering insurance' against political, contractual and credit risks. In addition to these external guarantees, sovereign guarantees are those offered by national governments to their own citizens, companies or subsovereign bodies when they borrow or attract direct investment (Winpenny, 2005).

> "Raising commercial finance for water (which has never been easy) has become more difficult due to the global financial situation since 2007, which has discouraged new private interest in water infrastructure projects and adversely affected the supply of risk capital and loan financing."

A number of donors and International Financial Institutions offer risk sharing products to encourage the growth of local current finance for water and other infrastructure. As a general principle, the risk of financial default can be managed by tailoring financial terms to the risk profile and expected cash flow of the project concerned. For large and complex projects it is becoming common to blend different types of finance (commercial loans, concessionary loans and grants, equity) to achieve an acceptable overall mix.

A recent review of innovative finance for water notes that commercial funding of all types has suffered from global financial turmoil. Instruments such as guarantees have been underutilized, and the credibility of complex structured financial products has been weakened. The long-term flow of commercial, including private, finance to water depends on reforms to its governance and operation, and novel forms of finance will remain limited by this constraint. However, there is considerable scope for blending public grant and concessional funds with commercial sources (OECD, 2010*b*).

CHAPTER 13

Responses to risk and uncertainty from a water management perspective

Reducing uncertainty

One of the most direct ways of reducing uncertainty is to generate new knowledge or understanding of conditions governing water availability and quality in the present and in the future.

A multi-disciplinary approach to modelling and forecasting, involving parties from different sectors (ecologists, engineers, economists, etc.), allows for broader insights into how to manage water resources in the face of risk and uncertainty (see Box 13.1, *Integrated Water Resources Optimization Models (IWROMs)*, p. 328 in WWDR4).

Because uncertainty is embedded as a fundamental principle, adaptive management strategies allow decision-makers to alter the direction of projects and programmes due to emerging information gained by the learning-by-doing approach (see Box 13.2, *Adaptive management: Adaptation tipping points in current Dutch flood management*, p. 330).

Ecosystem-based disaster risk management is an increasingly attractive option for addressing problems as varied as river-basin flooding, urban flooding, and drought (see Box 13.3, *Risk-addressed examples*, p. 331). Another tool used in dealing with water-related disasters from a planning and risk management perspective is catastrophe modelling (see Box 13.4, *Catastrophe modelling as a tool for understanding and calculating risk in the insurance industry*, p. 332).

> "The natural environment can also be considered as 'infrastructure', as it supplies many of the same services as man-made infrastructure."

The necessary participation of various stakeholders at different levels and the recognition of the need to meet essential ecological demands bring an additional layer of uncertainty and risk to the equation (see Box 13.5 *Farmer managed groundwater systems in Andhra Pradesh, India*, p. 333).

Reducing exposure to threat and minimizing risks

New, updated and expanded water resources infrastructure can reduce the risks associated with climate change, hydrological variability and their impacts on water resources and systems. Adding new infrastructure can potentially take advantage of new technology. Reservoirs are controversial. Many are being planned and built in water scarce or energy deficient areas of the world, while in other areas (mainly isolated cases in countries with sufficient or excessive reservoir capacity) they are being removed in an effort to restore ecosystems. Dams and reservoirs are essentially risk-avoidance tools, based on knowledge of current conditions and variability.

The natural environment can also be considered as 'infrastructure', as it supplies many of the same services as man-made infrastructure. Infrastructure planning, particularly investing in ecosystems, can also take a no-regrets approach by anticipating greater variability, and planning for sustainability (see Box 13.6, *Mangrove restoration in Viet Nam*, p. 335). Wetlands, for example, can reduce peak flood flows and assimilate many organic wastes in the same manner as wastewater treatment plants (see Box 13.7, *Constructed wetlands for wastewater treatment in Bayawan City, Philippines*, p. 336).

Living with risks and uncertainties: Trade-offs in water decision-making

Limited water availability, growing and evolving demands, and competition for increasingly scarce financial and physical resources create difficult trade-offs for decision-makers, who must plan effectively under considerable risk and uncertainty.

Policy changes only occur when the costs of maintaining the status quo exceed the transaction costs of implementing change (Saleth and Dinar, 2004). In this vein, countries can view their transaction costs in different ways: some may see the deterioration of water and environmental resources as negative externalities not costly enough to justify current policy change, while others may view future water challenges as bearing higher costs which require current policy modification for future benefit.

Examples of community-based watershed management systems in countries such as India and Brazil provide evidence of the value of involving women's groups in maintaining and protecting their water sources (see Box 13.8 *Community-based watershed management in India and Brazil*, p. 337).

Not all trade-offs need have a negative side. There are indeed examples of win–win situations where efforts to address risks and uncertainties in and outside the water realm have led to multiple multi-sectoral benefits, and to benefits for water in the long term (see Box 13.9, *Ensuring reliable access to water for industrial purposes while providing a key pollution control service*, p. 340).

CHAPTER 14

Responses to risk and uncertainty from out of the 'water box'

Reducing poverty and greening growth and economies

Water is so close to the heart of social and economic development that it is difficult to address one without addressing the other. Yet short-term plans for poverty reduction and economic development are often undertaken without a long-term analysis of potential water trade-offs, creating unsustainable development pathways.

More development usually means more water use, and more water pollution is often associated with higher levels of economic growth. Choosing diverse economic growth pathways can therefore help to address risks and uncertainties related to water availability; however, very few countries have the option to do so because the trade-offs and political costs are so high and immediately felt.

In some cases, green growth entails turning a development challenge – for example, lack of access to chemical fertilizer – into a sustainable development opportunity (see Box 14.1, *Cuba uses organic agriculture for sustainable growth*, p. 345 in WWDR4). Following this model, existing water scarcity could provide a basis for technological innovation to help countries leapfrog towards greener economies, while avoiding the common risks faced by other countries.

Responding to climate change: Adaptation and mitigation

Climate change represents one of the greatest uncertainties currently facing human society. However, impacts at the local level are far less predictable. Adaptation pathways referred to as 'no-regrets' approaches provide benefits – developmental or environmental – regardless of the realization of a given climate scenario. In the absence of certainty regarding local impacts, it is important to plan development in a way that allows for a flexible response to various climate scenarios (see Box 14.2 *Reducing Emissions from Deforestation and Forest Degradation (REDD) with water co-benefits*, p. 346).

In many countries already suffering from low agricultural yields, efforts to promote no-regrets climate adaptation include measures that combine diversification out of agriculture, sustainable technologies for

> "Short-term plans for poverty reduction and economic development are often undertaken without a long-term analysis of potential water trade-offs, creating unsustainable development pathways."

achieving higher yields per inputs, and technology transfer for the promotion of more sustainable input use (such as land, water, fertilizers or labour).

Business decisions to reduce risk and uncertainties

Most business decisions on investments and modes of production make presumptions about the future and take account of risks and uncertainties. Many decisions that are uniquely motivated by the financial bottom line can also provide effective means of reducing risks and uncertainties related to water. These can be further encouraged by government policies such as taxation rates, or fiscal incentives for attracting investment and business in a given location, while legal frameworks also go a long way to reducing uncertainties by providing boundaries and defining incentives for the investment context. The opposite is also true. Governments may choose to attract investments that provide the highest value for water units, although examples of such types of decision remain unfortunately rare.

Approaches to ensure access to natural resources for production can also help to reduce risks and uncertainties related to future water scarcity by providing an additional water reserve for communities and the environment (see Box 14.3, *Restoring water provision in a dry area: Italcementi*, p. 347).

Tools such as the proper pricing and valuation of water resources can assist in risk reduction for businesses, particularly when water is a key input in production. They can help to highlight trade-offs, costs and benefits/co-benefits that would otherwise not be apparent to businesses (See Box 14.4, *Implicit valuation reduces business and water risks*, p. 348).

Other factors are also increasingly motivating businesses to take certain types of decisions, in particular related to business or brand image, reputational risk and social responsibility, which in turn lead to positive impacts on the resource (see Box 14.5, *Business decision to promote reputational advantage leads to water benefits*, p. 349).

Managing sectoral risks to generate benefits to water

In the absence of a comprehensive framework for managing the increasingly complex trade-offs between policy choices, one approach may be to manage sectoral risks in a way that seeks to maximize benefits of water, or that reduces the uncertainties and risks faced by water users. This can reduce the number of variables, drivers and determinants to be considered in a given policy or investment choice, yet help to create win–win situations.

Most large-scale projects for transportation now include some mechanism for reducing future uncertainties, particularly as regards climate change. These can have positive benefits on runoff and groundwater recharge with little or no additional cost (see Box 14.6, *Autovias's Waterway Program decreased the need for road maintenance while helping to recharge one of Brazil's most important aquifers*, p. 350).

Win–win benefits between water and health planning can be found as the world's concern over pandemics and rapidly transmissible animal and human diseases increases. Crowd sourcing can provide a tool for reducing risk and uncertainties in various sectors, from crises to pandemics, with side benefits for water management (see Box 14.7, *Crowd-sourced health information reduces risks and uncertainties for water*, p. 351).

Water usually features prominently in urban planning considerations, but the integration of water's uses and benefits is more recent (see Box 14.8, *Landscape analysis helps reduce uncertainties within urban planning requirements: The case of Oregon*, p. 352).

Mitigating risks and uncertainties

When it is not possible to minimize risks or to reduce uncertainties, it is sometimes possible to minimize the consequences through mechanisms that help share risk burden, or that mitigate the various negative consequences of a given possible outcome.

Insurance is one of the oldest risk mitigation mechanisms. Index-based (or parametric) insurance is emerging as a potentially powerful tool for risk management in all sectors. This form of insurance is linked to an index or event, such as rainfall, temperature, humidity or crops yields, rather than to the amount of actual loss (see Box 14.9, *The Caribbean Catastrophe Risk Insurance Facility (CCRIF),* p. 353.

Treaties and agreements have always been mechanisms to reduce uncertainties regarding future safety, provision of services or access to resources. Water treaties or agreements regarding water allocation in shared transboundary river basins are multiplying, and are often quoted as having side benefits for reducing other risks, through the establishment of trust-building mechanisms and a certain amount of predictability in stakeholder behaviours (see Box 14.10, *Creating cooperative security-based institutions around water in Central Asia*, p. 354).

Agreements and treaties signed for purposes other than water may help reduce risks and uncertainties regarding water, particularly where they provide mutual assurance of the other party's behaviour regarding natural resource use. Creating conditions for national and regional security can also generate multiple benefits for water – and become a mechanism for dealing with future water risks and uncertainties.

Main Message 5: Under global conditions of increasing uncertainty and risk, concerted action must now be taken by water managers, leaders in government, civil society and business at local, basin, national and global levels. It is critical that national governments assume leadership and integrate water as a priority in all key policy areas – trade and the economy, food and energy security, financing, public health and security – within their own countries as well as through global policy tracks, including the MDGs, CSD and UN Conventions.

CONCLUSION

Water is at the centre of the development nexus, and it has far reaching connections with every realm of human life – from the basic concerns of food, health and energy, to poverty reduction and beyond to industry, trade and the economy. Today most of these 'sectors' face a crisis. New approaches that will provide insight into possible futures – and where responses can set the stage for future prosperity and avoid imminent catastrophe – are called for.

Water constraints on sustainable development have created hotspots where multiple challenges mesh and result in a spiral of increasing poverty, conflicts, uncertainty and instability. This happens in all regions, though the root of the challenges may differ from one region to the next. In Africa there is insufficient investment in water infrastructure and accessibility, compounded by low levels of technical and institutional capacity, over-consumption and pollution, which creates increasing constraints on North African countries' economies. In Asia, growing population and urbanization create challenges for sanitation, and disputes between users as well as high exposure to natural disasters and extreme events exacerbate existing vulnerability, risk and uncertainty. Demand is ever-increasing within some Arab and Western Asian countries that are already facing severe water scarcity constraints, and in Latin America and the Caribbean, increased demand fuelled by intensive development of natural resources, trade and growing economies is also posing a challenge alongside weak governance systems and regulatory frameworks that are often inadequate to deal with the pressures.

There is a need to replace the old ways of sector-based decision-making with a wider framework that considers the multiple facets of the development nexus, and the multiple risks and uncertainties, costs and benefits of every decision, in light of a long-term goal. In this regard, national governments have a major contribution to make by creating stronger, more collaborative, flexible institutions, by adopting appropriate financing and regulatory mechanisms to ensure the long-term viability, sustainability and efficiency of water services and infrastructure, and by ensuring that water considerations are mainstreamed into everyday policy decisions as well as international governance processes. Water managers have a responsibility to continuously inform these processes and to raise awareness of the centrality of water in the development nexus.

The increasing recognition of the link between water and other aspects of development (e.g. the water–energy–food nexus) can be seen as a positive development for water, especially as some of the most prominent initiatives have been led by actors from the energy and food sector, and may be viewed as increased recognition of water's importance in socio-economic development. Without fully implemented (and adaptable) plans for IWRM, the 'nexus' dialogue creates a pragmatic and substantial opportunity for informed decision-making outside the 'water box', complementary to IWRM. There have been advances towards IWRM as well: preliminary findings from a 2011 UN-Water global survey to determine progress towards IWRM show a wider adoption of integrated approaches with significant impacts on development and water management practices at a country level. There have also been some advances made under the recent UNFCCC Conferences of the Parties (COPs).

The most recent economic crisis could be seen as an opportunity; it provides an occasion for reflecting on a desired collective future, and it provides a critical glimpse of the interconnections between countries, sectors and policies. Similarly, looking at the future through a water lens also provides the insight needed to make decisions that maximize benefits to people, the environment and the global economy.

The financial, food, fuel and climate crises are, even individually, serious problems, but in combination their effects could be catastrophic for global sustainability. The WWDR4 has sought to provide a new way of looking at our water reality, through the perspective of risk and uncertainty. It has sought to encourage different ways of thinking about the world's collective future by identifying tools and approaches and by demonstrating that win–win scenarios are indeed possible. Political and business leaders as well as water managers, water users and ordinary citizens have a unique opportunity to see past immediate challenges and risks and to effect long-term change towards sustainable prosperity for all, through water.

Notes

1 Water is said to have been *consumed* when it is used in evapotranspiration and does not return to the surface or groundwater resource.

2 Examples of large aquifers in this category are the Highland Plains and Central Valley aquifers in the USA, the north-west India plains aquifers, the North China Plain aquifer and the Australian Great Artesian Basin.

3 Calculation by UNESCAP based on data from UNEP (2002).

4 For more on the implementation of IWRM, see the UN-Water *Status Report on the Application of Integrated Approaches to the Development, Management and Use of Water Resources to the UNCSD Rio+20 Conference*, released 19 June 2012.

5 The ten others being agriculture, buildings, cities, energy, fisheries, forestry, manufacturing, tourism, transport, and waste management.

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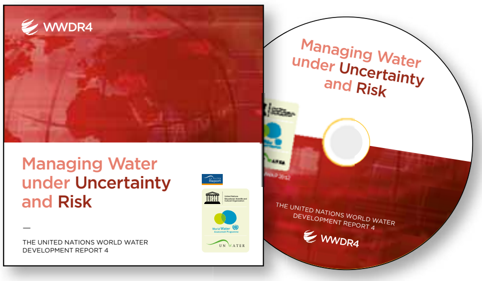

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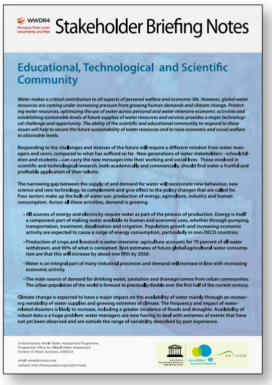

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The fourth edition of the United Nations *World Water Development Report* (WWDR4), published in March 2012, is a milestone within the WWDR series. In Volume 1, it introduces a thematic approach – 'Managing Water under Uncertainty and Risk' – in the context of a world which is changing faster than ever in often unforeseeable ways, with increasing uncertainties and risks. In Volume 2, 'Knowledge Base', contributions from UN-Water members serve to build a comprehensive review of regional and challenge area issues surrounding the world's freshwater resources. Like the earlier editions, the WWDR4 also contains, in Volume 3, 'Facing the Challenges', country-level case studies describing the progress made in meeting water-related objectives.

The WWDR4 seeks to offer leaders in government, the private sector and civil society tools and response options to address current and future challenges related to the pressures driving demand for water and affecting its availability. The WWDR4, which for the first time has been mainstreamed for gender, also seeks to show that water has a central role in all aspects of economic development and social welfare, and that concerted action via a collective approach of the water-using sectors is needed to ensure water's many benefits are maximized and shared equitably and that water-related development goals are achieved.

This Executive Summary is an encapsulated view of the key issues from the WWDR4, presented in the same chapter structure as for Volume 1 to assist orientation. It provides readers with a preview to the in-depth discussion and supporting material around these issues they can anticipate in the parent report, which can be viewed as a reference work.

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UN-Water is the United Nations inter-agency coordination mechanism for all freshwater related issues. The United Nations World Water Assessment Programme (WWAP), a UN-Water programme hosted by UNESCO, brings together the work of 28 UN-Water members in the WWDR4.

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